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THE CHLORIDE ELECTRICAL STORAGE BATTERY.

[*Being the report of the Committee on Science and the Arts on the invention of Clement Payen*].

HALL OF THE FRANKLIN INSTITUTE.
PHILADELPHIA, March 29, 1894.

The Franklin Institute of the State of Pennsylvania for the Promotion of the Mechanic Arts, acting through its Committee on Science and the Arts, investigating the "Chloride Electrical Storage Battery," finds as follows:

The sub-committee appointed to conduct this investigation has had this battery under careful consideration for a number of months, and has investigated the several features which are claimed to give it merit. During the larger portion of the time a number of cells have been in possession of the committee, and have been placed upon a regular working circuit under the control of one of the com-

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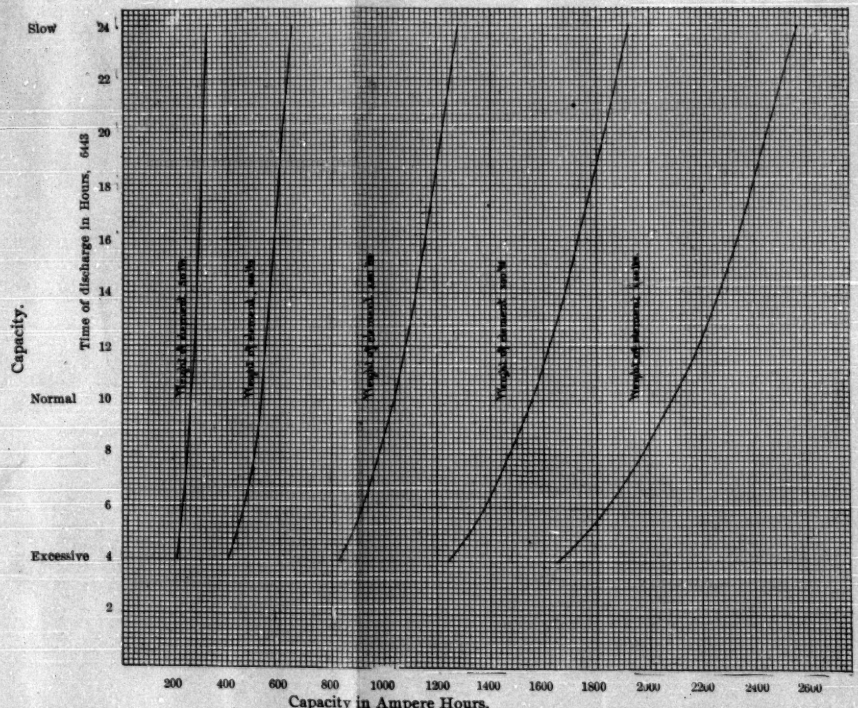

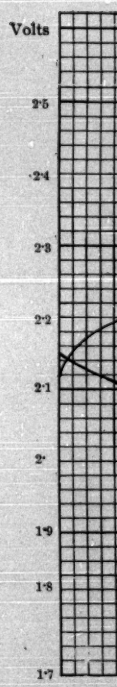

FIG. 3.—CURVES SHOWING CAPACITY AT DIFFERENT RATES OF DISCHARGE.

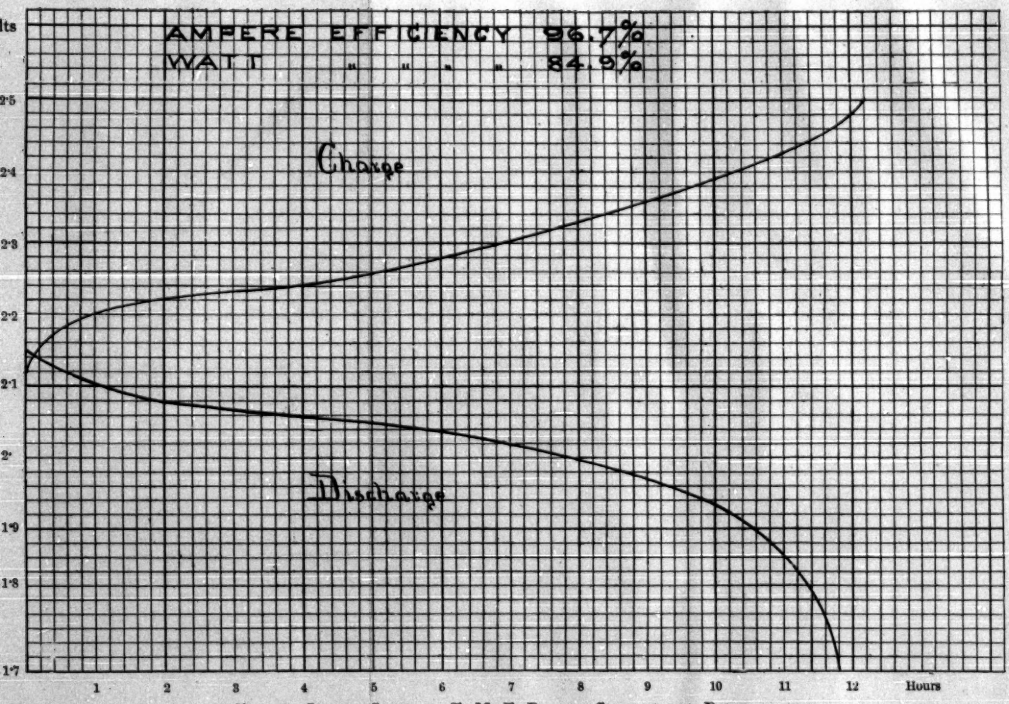

FIG. 4.—CURVES SHOWING E. M. F. DURING CHARGE AND DISCHARGE.

mittee's members, where they have been subjected to exactly the same usage as a number of other storage cells of other makers and of the same size, so that opportunity was thus given to obtain the results of the performance of the chloride storage battery in regular use, which is ultimately the final test by which the utility of all inventions and improvements must be measured.

The results of this examination have led to the opinion that this battery embodies certain features of construction which prove it, both theoretically and as verified by use, to be a distinct improvement over hitherto known forms of storage batteries. In order to fully appreciate these features of improvement, it will be necessary to recapitulate, briefly, a few well-known facts regarding storage batteries in general.

In all lead storage batteries, one of the objects desired is to obtain a large lead surface for small mass, as the capacity and discharge rates are strictly proportional to the amount of surface involved. This necessary maximum of surface has hitherto been obtained in one of two ways. The earlier way was to slowly eat out the lead plates by electrolysis until they had attained the requisite spongy condition, an affair of some time and expense. The later way—and the one which is generally practiced—is to cast a frame of lead, with raised right-angled ribs on each side, thus forming little depressed squares, or to punch a lead plate full of holes, which squares or holes are then filled with a pasty mixture of red oxide of lead in positive plates, and with litharge in negatives.

For several reasons cells made in this way have always given more or less trouble in service. In the first place, after continued use or during heavy discharges, a greater or less amount of mechanical disintegration of the positive plates would often take place, small fragments of lead and lead oxide dropping down between the positives and negatives, short-circuiting them and often causing further and more serious break-up, buckling and sulphating. Even when these particles are prevented from falling, their mechanical looseness causes poor contact with the supporting

lead frame, thus entailing increased internal resistance and heating with diminished output. This disintegration appears to be due largely to the fact that the lead oxide paste placed in the holes, is a mechanical rather than a chemical mixture, and hence that in changing from PbO_2 to $PbSO_4$ during the action of the cell, the molecules being only related to one another in a fortuitous manner, are easily broken up and thrust apart in the change of volume attending the chemical action. This, of course, seriously limits the life of a battery, and its utility for public service.

In the chloride battery, it is claimed and the committee's investigations go to confirm the correctness of the claim,

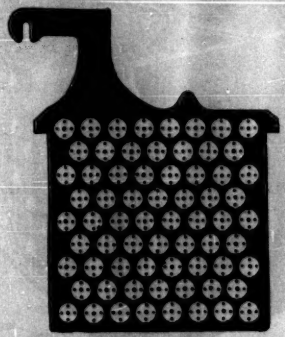

FIG. 1.—Type "E." Size, 7¾ x 7¾ inches.

that the method of construction is such that this disintegration is far less liable to occur. This mode of construction is as follows:

Instead of cementing lead oxide paste into or against a lead framing in order to obtain the necessary active material, the latter is obtained by a strictly chemical process. Lead chloride is taken, mixed with a given proportion of zinc chloride, and this mixture is then fused and cast in small squares in suitable moulds. When thus cast, the product is of whitish color and vitreous character, being quite brittle.

For the negative plates, these blocks are about $\frac{3}{4}$ inch

square and $\frac{1}{16}$ inch thick, and are cast in groups of four, these groups being united by portions, having, say, $\frac{3}{32}$ to $\frac{1}{8}$ inch thickness. For positives, the fused mass is cast in separate lozenges, each lozenge having a bevelled V-shaped periphery. These cut squares or lozenges are then placed in a suitable mould, and a molten mixture of lead and antimony, in proper proportions, is cast about them under high pressure, thus fixing them securely in a firm lead framing of somewhat more than the usual density. (The

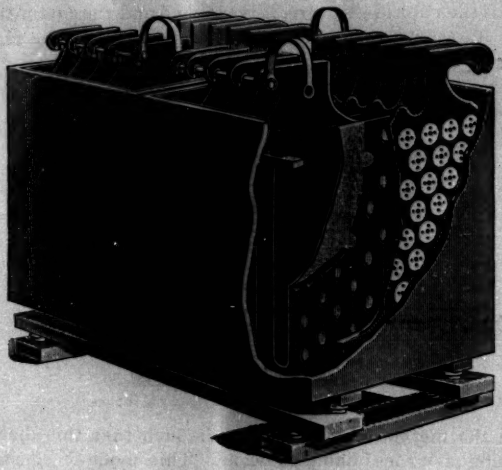

FIG. 2.

feature of casting under pressure is an improvement in manufacture, due to Mr. H. Lloyd, who is connected with the American makers, and the process is protected by patents granted to him). The connecting sheets of the squares making up a group and the V-shaped bevel of the lozenge serve to make their solidity of fixation exceedingly good.

The frameworks containing the chloride castings are then placed in a dilute solution of zinc chloride, together with

plates of zinc, the frames and zinc plates being alternated with one another and in metallic contact. This combination is the equivalent of a primary battery "dead short-circuited." The chemical reactions which occur, result in the removal of the zinc chloride and the chlorine of the lead, and there remains finally the dense framing containing squares or lozenges of spongy lead, which plates are then "formed" in, practically, the usual manner.

If a section of the spongy lead thus made, be examined, it is found that the metal is in a crystalline condition, and that the crystals are all uniformly arranged with their longer axes perpendicular to the surface of the plate. This provides interstices, so that the changes of volume occurring in the chemical reactions of electrolysis, may take place without exerting lateral pressure upon the crystals, or otherwise crowding them into a condition of break-up. These crystals are not, of course, mechanically and irregularly bound together, but are related to one another according to the laws of molecular formation, and are, consequently, much more strongly bound together than if they had been mechanically combined.

Furthermore, this crystalline structure presents the maximum obtainable surface for the given mass, an infinite number of inter-crystallic channels passing all through the material and the entire plate being of the same thoroughly spongy consistency, except in those small portions where the continuous lead framing is encountered.

The effect of this extreme porosity and surface area is to give the battery a maximum capacity for a given weight and size of cell, an item of great importance when considered with reference to the demands of traction. Very heavy discharges also can be taken from this battery, owing to the interstices between the crystals permitting changes of volume to occur without mechanical violence to the structure.

While the method of construction just described seems to accomplish its anti-disintegrating function perfectly, it has been thought best by the manufacturers, in order that there shall be no doubt about the matter, to introduce

between the plates a thin sheet of acid-proof fabric, so that any small particles which might fall away, could not make metallic contact with two adjacent plates and thus short-circuit the cell. The fabric chosen for this purpose is woven asbestos cloth. It might be thought that the introduction of this asbestos would considerably increase the internal resistance of the cell, but the fact is otherwise, the resistance of the cell being not appreciably higher than that of other lead cells.

This is undoubtedly due to the fact that the larger part of the resistance of most lead cells is that caused by poor contact between the lead framing and the paste placed in it. In the chloride battery this contact is exceptionally good, owing to the pastilles of chloride being so firmly bound by the framing cast under pressure as to compensate for any resistance due to the asbestos.

These batteries are, and have been for several years, operating successfully and in very large numbers in the city of Paris as a source of current for lighting purposes. A large plant has been in operation in this city in the building of the Provident Life and Trust Company for a year past, and a very large one has been installed at the station of the Germantown Electric Light Company, where it is said to have given, thus far, entire satisfaction.

The manufacture of this battery is protected by a large number of patents of the United States and of foreign countries, a list of which is hereto appended.* The essential features of the process of manufacture, however, are covered by the patents granted to Mr. Clement Payen.

Believing that this battery is a noteworthy and meritorious improvement upon many other forms of lead battery, tending to greater durability, greater capacity without increase of weight, and making possible heavier discharges without injury, the Institute, therefore, recommends the award of the John Scott Legacy Premium and Medal to to Clement Payen, the inventor.

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* Accessible for reference in the records of the Committee on Science and the Arts.

Adopted at a meeting of the Committee on Science and the Arts, held Wednesday, June 28, 1894.

JOSEPH M. WILSON, *President.*
WM. H. WAHL, *Secretary.*

Countersigned by

ARTHUR BEARDSLEY,
Chairman of the Committee on Science and the Arts.

APPENDIX.

The accompanying illustrations are introduced by way of explanation of the text of the foregoing report. *Fig. 1* gives a clear idea of the appearance and shape of the plates. *Fig. 2* represents two cells of the chloride accumulator with a portion of the tank broken away to exhibit the disposition of the individual elements. The cut also shows clearly the manner of connecting up the elements and cells.

The curves, *Figs. 3* and *4*, shown herewith, exhibit the working capacity and electrical efficiency of the chloride accumulator, and their interpretation will present no difficulties to the electrician.

WURTS' LIGHTNING ARRESTERS FOR THE PROTECTION OF ELECTRIC LIGHTING AND POWER CIRCUITS.

[*Being the report of the Committee on Science and the Arts on the improvements in Lightning Arresters invented by Alexander Jay Wurts.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, April 3, 1894.

The Franklin Institute of the State of Pennsylvania for the promotion of the Mechanic Arts, acting through its Committee on Science and the Arts, investigating "Wurts' Lightning Arresters," finds as follows:

The Institute, through a sub-committee appointed for the purpose, has carefully examined the claims set forth for these inventions as embodied in specimen arresters sub-

mitted, copies of patents granted and literature relating thereto. A considerable number of reports of effective operation have also been examined.

The various arresters produced by Mr. Wurts are intended for the protection of electric lighting and power circuits from direct and indirect damage from lightning discharges, and Mr. Wurtz has, apparently, studied this question in a scientific and very exhaustive manner.

With but few exceptions, all lightning arresters commonly used, up to the inventions of Mr. Wurts, have been based upon the fact that static discharges generally tend to "ground" by the shortest distance—even when obliged, in order to do this, to jump a considerable "air gap"—in preference to taking a longer path over a much lower resistance. Such arresters, therefore, have been essentially nothing more than two points or sets of points, one being "grounded" and the other connected to one or both legs of the circuit to be protected.

An arrester of this kind, while often affording a release from the static charge, would also allow the dynamo current to follow upon the arc so produced, thus producing either short-circuit or a dangerous "ground," and in both cases causing an interruption of the main working circuit. Hence, the more improved arresters of this type were so constructed as to break this dynamo arc as soon as possible. This is easily seen to be a remedy rather than a preventive.

Mr. Wurts perceived this fact and set himself the problem of constructing an arrester in which the dynamo arc could not start, rather than one which would break the arc when started. As far as can be judged from recorded data, he has succeeded in solving the problem in a very efficient manner, both for alternating and direct currents. We shall consider the separate forms separately.

The "Non-arcing" Metal Alternating Arrester.—This arrester, although the simplest in construction, is perhaps, the most notable of all Mr. Wurts' arresters. It consists simply of seven cylinders of metal, each one inch in diameter, and three inches long. These cylinders are mounted side by side, and separated from one another by $\frac{1}{64}$ of an inch. The

central cylinder is joined to ground, and the two outside ones to the two legs of a 1,000-volt circuit. They are knurled on their surfaces and fixed so that they can individually be rotated upon their axes. When a static discharge takes place either from one side to ground, or from both sides simultaneously, it is found that the flash is instantaneous and is not followed by an arc, while the temporary change in current value in the main circuit is too small to be easily appreciable. After-examination of the cylinders exhibits a slight black pit or burn where the discharge has passed.

Mr. Wurts has found that this non-arcing of the arrester is a property which is confined to certain particular metals and combinations of those metals. The most common are zinc and antimony. With these metals it is impossible to start and continue an arc when they are separated by an air gap of about $\frac{1}{64}$ of an inch. With longer gaps, *e. g.*, half an inch, vicious arcing is said to occur—a most peculiar fact.

Various explanations are offered to account for this non-arcing property, the one most generally accepted being that the metals immediately produce a non-conducting oxide vapor, over which the current cannot pass. The discovery and first use of these non-arcing metals is claimed by Mr. Wurts, and these claims are acknowledged by the issue to him of broad United States patents.

The Railway Lightning Arrester.—The non-arcing arrester just described is not suitable for any but alternating circuits. For electric railway circuits, a different arrester has therefore been devised. This consists essentially of a spark-gap joined by a non-inductive high resistance made of charred wood. A cover is then placed on the arrangement, and acts as a suppressor of any conducting vapor which might tend to be produced upon discharge taking place. The high resistance, or more properly, the conducting film between the electrodes, seems to act as a wedge through the dielectric and over which discharges pass disruptably to earth, making a sharp sound similar to the crack of a teamster's whip. An arrester of this type submitted to the committee, and

said to have been struck several hundred times, had suffered but little damage.

System of Protection for High Potential Circuits.—For the protection of circuits of high potential, Mr. Wurts has devised a system which consists in the placing at various points in the circuit of impedence coils of low resistance. These points, according to Mr. Wurts, become points of reflection for the high frequency surging which he considers the real form, as far as circuits are concerned, of lightning discharges. By means of these points of reflection, he conceives the electrical waves to be reflected back and broken up and eventually frittered away in the form of heat without actually getting to the generating of receiving apparatus at all. This form of protection, however, is not yet out of the experimental stage.

With the exception of the last described instrument the operative features of these various forms of arresters conform more closely to recognized laws than those of the devices previously known and used for the purpose. The instruments are cheaper to manufacture, and as far as the Institute has been able to ascertain, are very effective in preventing damage, and they protect without causing cessation operations.

In these respects, the Institute believes these inventions to be important improvements, and therefore recommends the award of the John Scott Legacy Premium and Medal to their originator, Alexander Jay Wurts, of Pittsburgh, Pa.

Adopted at the stated meeting of the Committee on Science and the Arts, held Wednesday, May 2, 1894.

JOSEPH M. WILSON, *President*,
WM. H. WAHL, *Secretary*.

Countersigned by

ARTHUR BEARDSLEY,
Chairman of the Committee on Science and the Arts.

THE CENTRIFUGAL PUMPING PLANT AT MARE ISLAND NAVY YARD, CALIFORNIA.

By JOHN H. COOPER, M.E.

A marked departure in centrifugal pump building in this country was inaugurated in the year 1884. During this year an example of superb stone dock architecture was nearing completion, within the extended precincts of Mare Island Navy Yard, California.

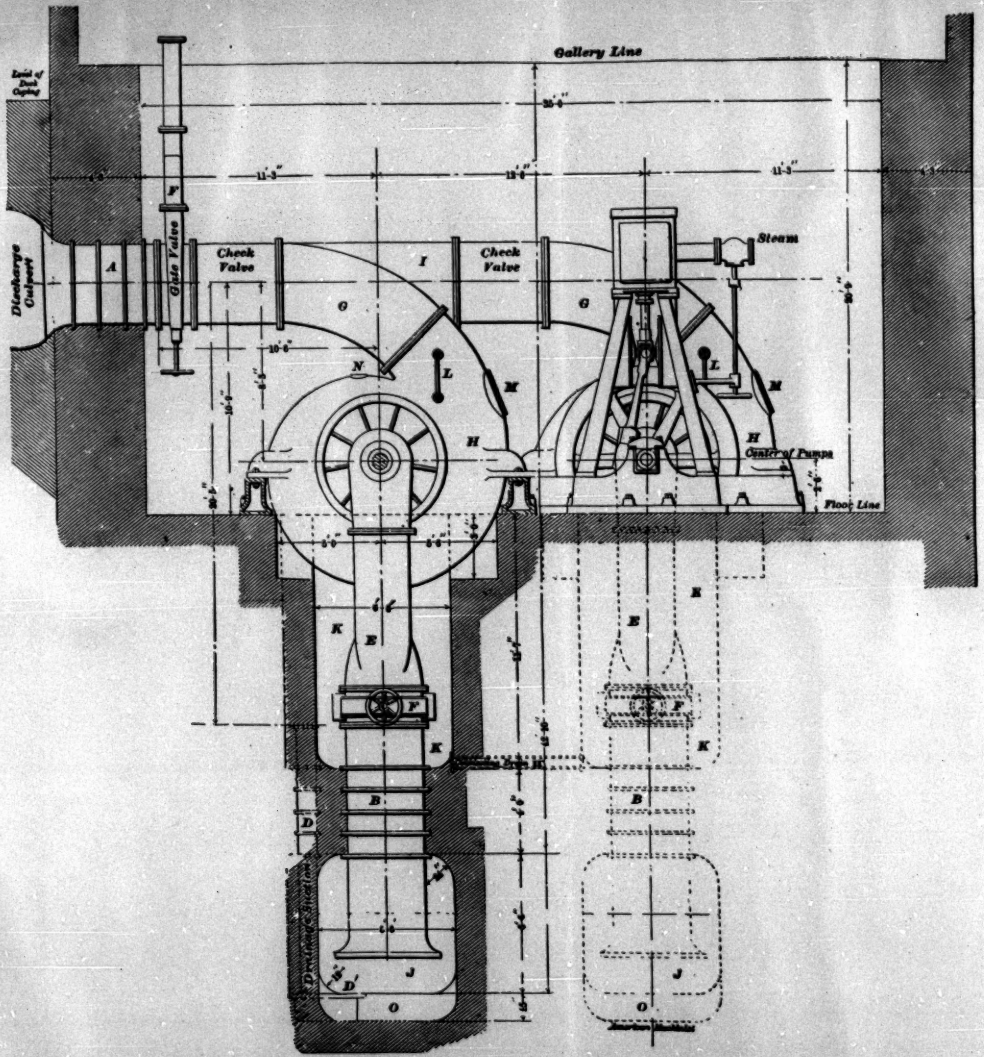
For emptying this dock of its seven to nine millions of gallons of water, within the practical limits of time necessary to safely secure a vessel therein, there would be required an adequately proportioned pumping mechanism.

To this end proposals were issued by the United States Government for a plant to consist of a pair of centrifugal pumps having an aggregate average discharge of 80,000 gallons per minute and a drainage pump with an average delivery of 2,000 gallons per minute, together with the necessary pipes and valves to connect them with the suction wells of the dock and to the discharge culvert communicating with the river, including propelling engines, foundation plates for supporting them and full equipment for operating the same.

No general plans or details whatever were furnished; the plant was to be delivered and erected in a house to be prepared by the Government beside the dock, to which also steam would be conveyed from boilers furnished by the department.

When completely erected by the contractors the plant was then to be tested by a committee of experts appointed by the commandant of the yard.

This contract was awarded to the Southwark Foundry and Machine Company, of this city, and bears date July 31, 1884, at which time Mr. Joseph L. Ferrel was manager, and to the writer of this article, then chief engineer of the works, was entrusted the entire formulation of the design and the



GENERAL END ELEVATION OF THE CENTRIFUGAL PUMPING PLANT AT MARE ISLAND NAVY YARD, CAL.

conception and arrangement of its details, in which latter he was ably assisted by Mr. T. H. Mirkil, Jr., who also erected and started the plant *in situ*.

Referring now to a general end elevation of the plant, as designed and erected for this dock, the main pumps *HH* will be noticed on foundation plates located considerably below the dock coping.

From the pump centers thirty-inch diameter breeches pipes *EE* descend to their joinings, with the horizontal forty-two-inch gate valves *FF* in their pits below the engine-room floor.

Extending beneath these will be seen the forty-two inch suction pipes *BB*, surrounded by flanges built in the deep concrete arches covering the suction conduits *JJ*. Through these conduits all the water from the dock flows into the suction pipes, to facilitate which the depressions *OO* were made immediately beneath their bell mouth inlets.

From the discharge ends of the pump casings, the water is conveyed through the rising bends *GG*, to the check valves, thence through the vertical forty-two inch gate valves *FF* into the discharge pipes *AA*, which are built into the heavy walls of the engine house, thence into the discharge conduit below the ground level, which receives the water from all the pumps and conducts it to the river.

The forty-two inch gate valves of the main pumps are steam-actuated, hydraulic-controlled, and are under the full command of the engineer at his stand by the throttle valves of the engines. They are also provided with starting screws turned by large hand-wheels to free the valves from their seats, to which they are liable to stick after long standing.

The check valves are supplied with visible index and supporting levers; they float upon the full stream of unobstructed water in their casings, flowing from their pumps when in normal action.

Each engine is directly connected to its own pump, but is independent of the other. The main pumps and engines are mounted upon attached bed-plates, as one firmly united and self-contained whole.

The steam cylinders of the main engines are 28 inches

diameter by 24 inches stroke; the drainage engine cylinder is 12 inches diameter by 10 inches stroke. These sizes were based upon the promised 50 pounds of steam per square inch.

The steam and manipulative equipment includes water gauges *LL* on the sides of the pump casings; steam charging ejectors on the summits of the same; hand adjusting steam cut-off valves and the usual automatic oilers; ladders into and foot-plates over the pits; man-holes for access to interiors, etc.

The pumping head of the main pumps varies from nothing at the start to about thirty-five feet at the finish.

The drainage pump, being used only for freeing the emptied dock of ordinary leakage, does all its work under the extreme head named, varying only from this by fluctuations of the tide without the dock and by slight changes of water level within the same.

Its suction pipe *D* is shown in place, rising from the pump box *D'*, covered by a grating at lowest level of the inlets *JJ*. A supplementary suction to the drainage pump relieves the pits *KK* of leakage, the two having a connecting drain pipe *W*.

In order to properly present the accomplished results of this initial centrifugal dock pumping plant, a reproduction of fitting paragraphs is made and here given, from the report of the Chief of the Bureau of Yards and Docks, on the occasion of its completion and first experimental trial. To these may very appropriately be added the concluding words of the Board on the accepted figures of the trials.

The writer is grateful for the unusual interest taken by the members of this Board in the reception and installation of this plant; the touch of a warm hand is manifest in the test as well as in the pen pictures given of its performance.

"During a pumping period of fifty-five minutes the dock had been emptied from the twenty-third to two inches above the sixth altar, containing 6,210,698 gallons, an average throughout of 112,922 gallons per minute. At one time, when the revolutions were increased to 160 per minute, the discharge was 137,797 gallons per minute; this is almost a

river, and is hardly conceivable. After the pumps were stopped, on this occasion tests were made with each in succession as to the power of the injectors with which each is fitted to recharge the pumps.

"In practice it would be impossible to secure a vessel in the dock, so rapidly was the water removed at the time of trial, and it is without parallel in the world that so large a dock, with its 7,000,000 gallons of water, has been emptied in fifty-five minutes, and it is almost beyond belief. One pump will do all that is required to empty the dock in use, and then it will require sharp work to properly shore the vessel to replace the rapidly-receding water.

"Everything moved most admirably, and the performance of these immense machines was almost startling. By watching the water in the dock, it could be seen to lower bodily, and so rapidly that it could be detected by the eye without reference to any fixed point.

"The well which communicates with the suction tunnel was open and the water would rise and fall, full of rapid swirls and eddies, though far above the entrance of these tunnels. It flowed rapidly through the culvert, and its outfall was a solid prism of water the full size of the tunnel projecting far into the river.

"The operation of this vast machinery was highly satisfactory. I went on several occasions down in the valve pits on the ladder of the casing, and to all accessible parts while in motion at its highest speed, and there was no undue vibration, only a uniform murmur of well-balanced parts, and the peculiar clash of the water against the sides of the casing as its velocity was checked by the blank spaces in the runner.

"This clashing of the water affords a means of detecting any faulty or unequal discharges from any of the openings of the runner. While moving at a uniform speed, this clashing has a tone whose pitch corresponds with that velocity of discharge, and if this tone is lacking in quality, or at all confused, there is want of equality of discharge through the various openings of the runner.

"To this part I gave close attention, and there was nothing

that the ear could detect to indicate aught but the nicest adjustment. The bearings of the runners worked with great smoothness and did not become at all heated. Through a simple, novel arrangement, these bearings are lubricated and kept cool. There is a constant circulation of water from the pumps, by means of a small pipe which completes a circuit to an annular in the bearings back to the discharge pipe while the pump is in motion, requiring no oil and making it seemingly impossible to heat these bearings.

"The large cast-steel check valves placed in the *embouchement* of the pump casing, it was thought might act to check the free discharge, and arrangements were provided for raising and keeping them open by a long lever key attached to their axes of revolution; but, to our great surprise, at the first gush from the pumps, these valves, weighing nearly 1,500 pounds, were lifted into their recessed chambers giving an unobstructed opening to the flow, and they floated on its surface unsupported save by the swiftly-flowing water, without a movement, while the pump was in operation.

"The steam-actuated valves in the suction and discharge pipes worked very well, and the water cushion gave a slow uniform motion and without shock either in opening or closing them.

"The engines worked noiselessly without shock or labor. At no time during the trial was the throttle valve open more than three-eighths of an inch.

"The indicator cards taken at various intervals gave 796 horse-power and the revolutions did not exceed 160 at any time, though it was estimated that 900 horse-power and 210 revolutions would be necessary to attain the requisite delivery; so that there is a large reserve of power available at any time.

"The erection of this massive machinery has been admirably done, the parts, as sent from the shops of the contractor, have matched in all cases without interference and, when lowered into place, its final adjustment was then made without the use of chisel or file, and has never been touched since.

"The joints of steam and water connection were perfect, and the method of concentrating all valves, waste drips and important movements at the post of the engineer in charge gives him complete control of the whole system of each engine and pump without leaving his place, and reduces to a minimum the necessary attendance. All the parts are strong and of excellent design and workmanship, simple and without ornamentation. Looking down upon them from a level of the pump-house gallery, they are impressive and massive in their simplicity.

"The Government is well worthy of congratulation in possessing the largest pumping machinery of this type and of the greatest capacity in the world, and the contractors have reason to be proud of their work.

"There is nothing that a thorough trial has found wanting or that a careful retrospection suggests. It is ready for the purposes intended at any moment, so far as pertains to this department, and it is with a feeling of profound gratitude that I am enabled to make this announcement to the Bureau.

"Prior to the trial of the pumps, a simple, though delicate registering apparatus, was erected in the pump house, indicating on a large dial the number of feet and inches of the water in the dock above the suction tunnels. This furnishes most accurate information to the engineer of the quantity of water in the dock and the performances of the pumps, and warns him of the time for stopping the large pumps without incurring any of the risks involved in pumping too low and getting air into the pump casing.

"It worked most admirably during the trial, and was a check on the data taken at other points.

"In addition to the two forty-two-inch pumps for emptying the greatest bulk of water from the dock, an eight-inch centrifugal pump was furnished by the contractors for completing the discharge and for continuously removing the water of infiltration, which, though small in quantity, must be removed in order that its accumulation may not cover the floor of the dock and interfere with the operations of the workman.

"In order to test this pump the large gates in the drainage tunnels, near the invert, were closed down, leaving these tunnels full of water, and the water in the well at a level of the water in the dock. This gave a fixed and known quantity to be removed, and sufficiently large to afford a fair run of the pump. This was pumped out on two occasions, each of which gave a record beyond the requirements of the contract.

"The working of the engine and pump was all that could be desired, the steam pressure being fifty-five pounds per square inch, and the revolutions 350 per minute, the horse-power developed, as taken from the indicator diagrams, was thirty-two.

"The pump was charged with certainty and rapidity by means of the ejector at various levels of the water. This pump has been frequently used since its erection, and previous to the trial in removing the seepage water from the dock and has always worked admirably."

The board appointed for testing these pumps consisted of Captain F. V. McNair, U.S.N.; Chief Engineer George F. Kutz, U.S.N.; Civil Engineer C. C. Wolcott, U.S.N.; who conclude their report as follows:

"In making these tests, such conditions were imposed as would obtain in the usual operation of docking vessels; that is, the height of water in the dock was what it would contain were it occupied by an ordinary vessel, and with the state of the tide which would be chosen for beginning to discharge the water, giving a minimum of quantity to be removed. This, at the same time gave a somewhat severer test in obtaining the requisite average of discharge, for with the water in the dock at higher levels, the quantity discharged in the first few minutes would be very large, bringing the average for the whole to a much higher figure.

"During the trial, careful inspection of the machinery showed freedom from unusual vibration, and smoothness in action, as the result of well-proportioned and well-balanced parts, and with uniform velocity in revolution indicated equal discharge from all the openings in the runner.

"Tests were also made with all the pumps as to the abil-

ity of their steam ejectors to recharge them, and to continue pumping in case of stoppage, or their losing the water at any point, when the level of the water was below the centre of the runner.

"The trial was had in the case of the main pump with the water in the suction tunnel on a level with the fifth altar of the dock; with the small drainage pump it was recharged when the water had entirely left the floor of the dock, and was not more than two feet above the floor of the well.

"Finally, the board have to report that, the obligation of the contract in the mean capacity of discharge per minute of each of the main pumps and of the drainage pump, after a fair and thorough test, has been fulfilled, and that the general efficiency of each and all of these pumps is highly satisfactory."

4724 Springfield Avenue, Philadelphia, Pa., September, 1894.

ELECTRICITY IN THE MODERN CITY.*

By Thomas Commerford Martin.

[*Concluded from p. 211.*]

If you are not familiar with the statistics of electric railway work, I may commend them to your observation as another striking instance of the manner in which, in America, the visionary schemes of the inventor soon become the solid realization of the public. They show, I think, that in this respect, as in so many others, electricity is worthy of the graceful compliment that Florizel paid to Perdita: "What you do, still betters what is done."

For the vast majority of our cities and towns, electricity becomes the sole means by which they can enjoy that which counts for so much in the sum of comfort and convenience —swift, cheap, frequent and profitable transportation. Moreover, as Captain Eugene Griffin once put it: "The public was realizing that a good street railway security is bet-

ter than a Western railway bond or stock. Electric railways will pay where no one would dream of building a horse road, and when the public taste is whetted for electrical securities we shall see a marvellous increase in the number of roads." That saying has already come to pass, and to-day, where you will find one new horse road or cable road projected, you will find at least 100 electric. That is near the actual proportion, with such results that the *Philadelphia Stockholder*, in a recent issue, published a diagram showing graphically that the dividends on all the street railways of the country are three times as large as those on the steam railways. It need not be wondered at, therefore, that local capital, which has hitherto been the mainstay of street railway enterprises, will have to compete with the investors of our centers of finance.

But I am not so much concerned with that, for a question of greater interest is that as to the effect of this change on the husbanding of other resources—I mean the vital, physical, moral and social elements of our city life. I look upon electric roads as a beneficial agency in the more uniform distribution of a happier population around any center, thus increasing the value of outlying property, and, by the stimulation of local trade, enhancing the profit earned in the area lying within the region thereafter more legitimately restricted to business occupancy. If a man is compelled to live in a city and pay high rent because rapid transit facilities are bad, he takes Irish views on the landlord question. If he lives far out and wastes his time and strength on a tiresome journey, he is an active sympathizer with the eight-hour movement. We all know that the value of real estate is affected by the concentration of population, and this is true of both office and dwelling property. But it is a singular fact that the discontent as to high rents does not apply to the occupancy of offices, and I think that one of the reasons of that has been that the majority of the workers in offices are either able to dwell nearer the scene of their labors, or, if living further out, are less restricted as to regular hours of service. But for the great bulk of any community the matter of dwellings is a most serious one, touching the deepest problems of life and conduct. Mr. Carroll D. Wright, the United States

Commissioner of Labor, put the case in a nutshell in a recent *Popular Science Monthly*, when he said: "By the old methods of transit from suburbs to the heart of the city, a workingman going into the city of Boston was practically obliged, while working ten hours at his occupation, to spend an hour on the horse railway, where now, by the use of the electric car, he can go and return from his place of work in half that time, thereby actually adding to his own time half an hour each day, practically reducing his working time from eleven hours to ten and a half hours, without reduction of wages and without increased expenses for transportation. The question of rapid transit, therefore, as seen by this simple illustration, becomes an ethical consideration; for if there is anything to be gained by adding to the time which men have at their disposal for their own purposes, for intercourse with their families, for social improvement, for everything for which leisure is supposed to be used, then the question of rapid transit is of far greater importance than that of saving money, either to the man who uses the transportation or to the company that secures dividends upon its stock."

To make such toiling men owners of their little homes seems to me infinitely more important than making them stalwart Republicans or Jefferson Democrats, and I would ten times rather see them sitting quietly and free in the shade of their rural fig trees than parading through the city mud and waving the banner of a ward boss, whose prosperity depends on their being under his thumb or heel, while they live in garret or cellar. No modern city anywhere has anything like adequate means of travel; and yet, when the time comes for a great city to exert itself, how the facilities of rapid transit make for a pure city government! Old London is herself an instance of this, for so long as her swarms hived within narrow limits she was municipally as corrupt as any city could well be; but to-day, with her population spread over a vast suburban area, and with multiplied means of communication, she governs herself as I believe no other community in the world can claim to do.

I am fully satisfied that much of the modern lack of indi-

vidual interest in city life on its municipal side has arisen from these two things—the crowding together of the poor, and the living in remote suburbs of another part of the population, which, when it gets home, is too tired to come back even to resent public robbery and jobbery. But the evil has been a deeper one than this. Throughout this great country of ours there are about 11,500,000 dwellings, with nearly one family to each, that family being just a fraction short of five persons. But in New York City we have only 81,828 dwellings with an average of nearly four families per dwelling. As a matter of fact, only about twelve per cent. of all the families in New York have homes to themselves, and eighty-two per cent. live in tenements. Does anyone doubt that with more homes—or better rapid transit, which means the same thing—New York would be a better city? Does anyone doubt that if in better touch with her outlying suburbs, full of houseowners, Philadelphia would have a higher type of popular government than it now enjoys?

That electric roads do stimulate and vivify city life, is apparent to all who study the subject. We find at once that levelling up of values and that distribution of prosperity which is the aim and sum of all political economy. It is not at all an infrequent thing to see the adoption of electricity doubling and trebling the traffic of a street railway, while a permanent addition of thirty per cent. to the traffic is now taken as an absolutely safe minimum. It is unnecessary to point out what that means. Cambridge, Mass., with a population of about 70,000, pays the West End Company, of Boston, 50,000 to 60,000 fares daily, corresponding to five-sixths of the population on a single fare basis, and giving a total average of nearly 250 trips per year per inhabitant, or five times the general average for twenty-two other Massachusetts communities. As to the increased value of property, we may take the case of Brookline, Mass., where, owing to the service of the West End road, running at a suburban speed of twelve or fifteen miles an hour, the real estate valuation has risen far above $30,000,000 from about $17,000,000 in 1885. Every member of the community is

the richer for that change, and the same assertion might be made for scores and scores of other communities. The little electric road, that has cost, perhaps, $100,000, has added ten times that value to the property; it has brought the price of land within the means of the people, to whom the ownership of house and home, even in this boundless America of ours, began to be as improbable as the possession of an Atlantic steamship.

Moreover, look at many of the additional uses to which these electric roads are being put. In some cities they carry the mails regularly. In others, their extension of the express system has given an entirely new development to the freight business. In many cities there are funeral cars that simplify and cheapen the heavy burdens of decent burial. Several roads have been built as links between steam roads, while others give the people access in the summer time to breathing spaces that were previously beyond reach. I have even heard of hotels whose peculiar feature of excellence is, that they have electric cars running to and from the depots for the particular benefit of their patrons.

It may be said that I am very much alive to the advantages of electric traction and not a little blind to their defects. Perhaps that is true, but it has seemed to me that the assailants of electricity did not need any help. I am not talking about a perfect thing. Few of our electrical applications have seen their best days. I am free to confess, however, that it does disgust me to hear people complaining about the ugliness of the overhead wires or the dangers of the trolley, while they complacently tolerate evils that really have an existence. I echo the remark of Mr. Frederic Harrison, that "To decry steam and electricity, inventions and products, is hardly more foolish than to deny the price which civilization itself has to pay for the use of them." When I hear people in New York abusing overhead wires and almost in the same breath advocating an extension of the elevated railway system, I pray God to spare me from any such obliquity of vision.

Not long ago, a fellow-citizen of mine, who was railing

against overhead wires along a certain street, was unable to say on which side of the street the wires were. Now, I will take second place to no man in civic pride or in admiration of fine thoroughfares, but I fail utterly to see that a good piece of overhead trolley construction is inferior in comeliness to the architecture of most of the streets it occupies. On the contrary, I have seen many a street, whose whole air of thrift, and whose only pretence to trimness and symmetry, was due to the wires that ran above it. Another point is the accusation of danger brought against electric cars. Now, as a matter of fact, electric cars in this country have already carried more passengers than would equal the entire population of the globe, and I defy anyone to point to a single instance in which a passenger has been killed or even injured by the current. Other accidents you will have, of course. Electric and cable cars travel faster than horse cars, and hence, there is, upon their introduction, an increased number of accidents from the unfamiliarity of pedestrians and drivers with their speed. But, even if this higher number should be maintained, I must insist that against it shall be put the saving of life and the increase of health that come from the adoption of a method which gives back to the dweller in the city his birthright in the country.

One more point, and I will refrain from the discussion of a topic that has so many aspects. It is commonly and truly understood that the resort to electricity, while accompanied generally by large investment, leads to a saving in operating expenses. For example, the Rochester Street Railway, for June, 1891, showed earnings with electric cars 22·77 cents per mile, and expenses 11·07 cents; while their cars with horses earned 14·37 cents and cost 12·06 cents to run. In other words, the net earnings with electricity were 11·70 cents, and with horses 3·31 cents. The assumption generally is that the city granting the franchise should share directly from this saving, as well as indirectly from the increment in the taxable value of property, and from taxation of the road in the ordinary way. In many respects the theory is right, but as our old friend, Captain Cuttle, would

say: "The bearings of this observation lies in the application of it."

This very desire to exact a share in the benefits of a new thing, so beset and burdened the electric light in England, that, even to-day, though now encouraged by less grasping legislation, it is still scarcely known. In New York our experience in putting up street railway franchises to the highest bidder has taught a painful lesson in the repression of new enterprises that are badly needed.

The question very often resolves itself into the balancing of advantages. It may, on the one hand, be well to get a few thousand dollars in extra taxes; but if this exaction, well meant though it be, compels the company to use old and inferior rolling stock, or to curtail the service on lines it would like to build up, then the city would be richer in the long run if its citizens could ride about in new cars and did not have to linger about street corners on bleak nights waiting for the car that seems as though it would never come. There is open the alternative of city ownership, a plan which appears feasible only when the city owns the road and leases it. This practice obtains in Glasgow and Liverpool, and, as might have been expected, the double responsibility leads to no end of trouble. Our American cities may, perhaps, be in shape to try the experiment, after they have learned how to keep their existing highways in decent condition.

I hope soon to see overhead trolley cars supplemented by storage battery cars, and by conduit trolley cars, and, more particularly in large cities, by elevated and underground electric roads. Evidently it is only with tracks above or below the surface that we can ever attain the high speed to which the phrase "rapid transit" will justly apply; and I think that by-and-by, in our largest cities, travel will be wholly by electricity, above or below the street surface. It is for that reason, but in no other sense, that I regard the trolley system as a make-shift. On the contrary, it is worthy the praise and support of every American proud of American inventive genius, and of the quick American appreciation of new methods and ideas.

There remain many branches of electrical work that I have not touched upon, which are really of vast importance to the dweller in the modern city, but I have devoted the hour to the leading three—the communication of news and intelligence, the use of electricity for light, heat and power, and the employment of the electric motor as a means of traction—thus affecting the three greatest elements in our daily city life.

AËRIAL NAVIGATION.

By. A. F. Zahm, Johns Hopkins University.*

In his lecture on aërial navigation delivered before the students of Cornell University in 1890, Mr. Chanute began his remarks with a hesitancy amounting almost to reluctance, seeming to entreat the young men not to believe that the study of such a subject was a more than probable indication of failing mental vigor. If he could appear before you this evening it would doubtless be very gratifying to him to realize that an audience of sober scientists and engineers were willing to listen for an hour to hear something of the venturesome art of flying through the air.

It is indeed a source of pleasure to all earnest students of aërial navigation to observe the general awakening of public interest in their efforts within recent years; for it lends, as it were, a dignity and reasonableness to their pursuits which is at all times comforting. It almost inspires them with the courage to experiment in the broad light of day, to forsake the garret and the lone watches of the moon, to come out from behind the hedge rows and to look the inquiring world frankly in the face. Let us hope that their achievements may justify the public attention and that the present sympathy of engineers may but prove one of the earlier manifestations of

> "The prophetic soul
> Of the wide world dreaming on things to come."

* A lecture delivered before the Franklin Institute, January 5, 1894.

Just at present the public seems, if possible, even more confident of the possibilities of aërial navigation than the investigators themselves. It seems quite prepared to abandon the boat and the railway car, with all the pleasures of land and of sea, for the winged chariot and the untrammeled vast above us; quite ready to realize the visions of Darwin and of Tennyson, even to the extent of seeing "the heavens fill with commerce" and of witnessing "the nations airy navies grappling in the central blue." The experimenters, however, would be more than contented if they could but guide their adventurous way and hold an even course through the treacherous depths of the atmosphere, leaving to other times the more ambitious adaptations and the fuller enjoyment of their labors.

I think we may profitably notice four classes of aërial navigators who have accomplished some good work and who promise further achievements of value. We may notice (1) the "*passive balloonists*," or those who employ no motive power and make no endeavor to control their course through the air more than may be effected by choosing favorable currents; (2) the "*active balloonists*," or those who employ the utmost attainable motive power in their endeavor to cope with the prevailing winds, and to pursue their course at will in any direction; (3) the "*active aviators*," or those who would fly through the air in massive unbuoyant machines actuated by wings or screws, and dependent both for support and propulsion upon the energy of extremely light and powerful motors; (4) the "*passive aviators*," or those who are trying to soar on outstretched wings depending for support and propulsion entirely upon the energy of the wind.

PASSIVE AËRONAUTICS.

Though it has long been a dream with the passive or free balloonists that they may discover in the upper atmosphere extensive trade-winds in which they may sail with security and precision over vast distances, the most valuable outcome of their explorations thus far has been the recording of phenomena observed in the regions of the clouds.

These phenomena have proved of immense interest to meteorologists, and are likely to receive considerable attention in the immediate future. Propositions for further exploration of the upper air are being discussed in the meteorological journals and societies which would indicate that this is one of the most serious problems calling for immediate solution. It will certainly prove a magnificent achievement both for meteorology and aëronautics if the great trade-winds of the upper atmosphere can be plotted as definitely as the currents of the ocean.

It has long been a conviction with aëronauts that such currents exist, and that they are well worth serious study. Mr. Wise, the pioneer of aëronautics in this country, was so confident of a steady west wind a few thousand feet above us, that he thought it could be employed for regular voyages across the continent, if not across the ocean. Mr. Hazen, of the Weather Bureau, is no less enthusiastic about the existence and importance of such winds. In answer to my inquiries on this subject, he replies: "There is no question that the currents above about 6,000 feet have a pretty steady motion from the west. On Mt. Washington, N. H., at a height of 6,300 feet, the winds are constantly from the west. It is safe to say that the irregular or circulatory winds of our storms very nearly disappear at a height of about 4,000 feet, and from that height to 6,000 feet the current becomes more and more steady from the west. Here, in Washington, I have never seen a true cirrus moving from the east (N. E. to S. E.). These clouds range from 10,000 to 20,000 feet in elevation, though at times they reach 20,000 to 25,000 feet. At Mt. Washington, a good number of instances have been recorded of winds blowing eighty to ninety miles an hour and lasting twenty-four hours or more. It is now pretty well known when we may expect such winds, and there ought not to be the slightest difficulty in making the voyage from Denver to New York, and after that from New York to England."

While on this point, I may mention a most interesting paper on the exploration of the upper atmosphere, contributed to the Chicago Conference on Aërial Navigation, by M.

DeFonvielle, of Paris, in which he describes some records obtained by M. Heremite at extraordinary altitudes. It had formerly been proposed to employ closed and heated cars to protect aëronauts from asphyxia and freezing at elevations above six or seven miles, but the expense of constructing a balloon so equipped had prevented such enterprise. M. Heremite accordingly determined, in 1892, to construct very light balloons of goldbeater's skin, and of sufficient capacity to carry up self-recording instruments, believing that the balloons might float for some hours at random, and, on falling to earth, be discovered by someone who could telegraph to him at Paris, according to printed instructions sent with the balloon. In this he was not disappointed; for it was found that in a well populated and civilized country like France, a large percentage of the balloons could be recovered with their instruments in good order.

On the 21st of March, 1893, such a balloon, measuring about twenty feet in diameter, was liberated at mid-day, and rose with great rapidity to an altitude far exceeding any height ever attained by an aëronaut, where it floated till late in the afternoon, descending to the earth about seven o'clock in the evening. It was recovered the next morning, and when the records were examined, it was found that the balloon had risen from the earth with a velocity of nearly twenty miles an hour, having ascended 8,530 feet in five minutes after its departure. In twenty minutes it had attained an elevation of eight miles, and shortly afterward soared up to its maximum height of 52,494 feet, or very nearly ten miles, which far surpassed anything of the kind hitherto achieved. The temperature steadily fell as the balloon arose until the barometer indicated an elevation of 45,920 feet, whereupon the ink in the recording thermometer froze. M. Heremite estimates that at the maximum altitude attained by the balloon, the temperature of the surrounding air was 256° below zero, Fahrenheit, thus indicating that the temperature of the atmosphere fell on an average 1° for each 165 feet of ascent above the earth's surface. He further estimates that the temperature of absolute zero,— 459°·40 F., will be reached at a height of 85,303 feet, or a little over

sixteen miles, and that this altitude may perhaps be attained by his exploring balloons.

These facts, however, interesting and valuable they may be in their relations to the other sciences, do not so directly concern us here as the records of the velocity and direction of the wind. M. DeFonvielle informs us that the paths of the balloons which rose to a great elevation above Paris indicated a general eastward direction for the currents in which they sailed and that their velocity did not appear to be very great. This latter observation is in striking contrast to the extraordinary figures given by some observers in America who assure us that the velocity of the upper clouds as determined by triangulation, is quite usually between 75 and 100 miles per hour.

It is understood that the experiments above described are still continuing in France and it is hoped that similar ones may be attempted in other civilized countries, for whether or not they result in furnishing us with a chart of the atmosphere they will doubtless throw light upon a multitude of problems. The extraordinary results set forth in DeFonvielle's paper have not been satisfactorily verified as yet, but I have thought proper to mention them because the investigations are still in progress and are calling forth no little comment.

ACTIVE AËRONAUTICS.

As it is manifest that no probable combination of differently blowing winds in the upper atmosphere could completely serve the demands of a perfect system of aëronautics, inventors have from the beginning made strenuous efforts to guide and propel their vessels independently of the weather. A vast number and variety of schemes have been proposed, most of them evincing a paltry knowledge of mechanics or of anything else; for it has ever been a grand passion, an alluring dream, with the imaginative inventors, to sail at will amid the pomps and glory of the clouds. Yet, however laborious and earnest their efforts may have been, the service they have rendered mankind must be regarded as of a negative kind. The second rate inven-

tor can usually be of some service in the advancement of mechanics by suggesting improvements of detail; but when he dares to create a complete air-ship alone, the burden of it is sure to wreck his mind and empty his purse.

The problem of navigating the air has proved to be a most formidable one; for it presents nearly all the difficulties of submarine navigation with few of its facilities. The fickle element can offer but one-eighth of one per cent. of the support of water; it is forever changing its density with sunshine and shadow, and a multitude of causes; it sweeps along quite usually with torrential velocities; it is vexed with whirls, and undulations, and breakers for the most part invisible to the eye. It offers, indeed, a proportionately small resistance to progression; it exhibits an almost negligible viscoscity; but the frail structures which weather it must possess enormous dimensions and carry huge propellers actuated by despairingly light and powerful motors. Finally to the host of other difficulties must be added the financial one; for small vessels are of small scientific value, and large ones bankrupt the experimenter without bringing return.

Yet in spite of these odds, men of excellent judgment have dared to stem the currents of this nimble sea, and have already won a measure of success. The labors of the indefatigable Frenchmen, of Meusnier, of Giffard, of Dupuy de Lôme, of the Tissandier brothers, and finally of Renard and Krebs, have steadily advanced the construction and capacity of the dirigible balloon till it may almost be said to vie with its maritime neighbor in grace and speed. Giffard's balloon, which was constructed in 1852, and was propelled by a steam engine actuating a screw, is reported to have sailed with a speed of four and a half to six and a half miles an hour, or about the same as that of the first steamboat. Dupuy de Lome, ten years later, greatly improved the construction of the balloon, but, unfortunately, employed men instead of a steam motor to operate the driving screw. Still he attained a speed of over six miles an hour. Eleven years later the Tissandier brothers, employing a similar balloon driven by electric motive power, obtained a speed

of 6·7 miles an hour, and two years later raised this record to 8·9 miles an hour. In the meantime the French government had been preparing a balloon which for the beauty of its outline, the strength of its construction and the perfection of its propelling apparatus, should excel everything thus far attempted. When finally launched August 9, 1884, it immediately rose in the air and began its memorable voyage from Chalais at a speed of nearly eleven miles an hour.

It may be well to give a fuller description of the construction and performance of this famous balloon, called La France, whose successful manoeuvres created so much enthusiasm and excited so much speculation in the past decade. In outline it looks not unlike a great cigar placed horizontally in the air. It measures 165 feet in length, 27·5 feet in its greatest diameter, which is one-fourth of the distance from the front end, and possesses a buoyancy of 4,400 pounds. Beneath the balloon proper a long, narrow car, made of bamboo and covered with silk, is suspended from the cords of the netting which embraces the balloon throughout nearly its entire length. The car is 108 feet long and 6 to 7 feet across, carries at its forward end the propeller, at its rear, the rudder, and between them, the aëronauts and the batteries and electric motor which supply the propelling power. The length of this balloon is six times its diameter, which is a much greater proportion than had been exhibited by any of the successful vessels which had preceded it. Its centre of traction is also placed relatively much nearer the centre of resistance, and the sustaining cords are disposed so as to offer slight resistance to progression, while at the same time affording rigidity and permanence of shape

The electric motor and battery which furnish the propulsive power of this balloon, were designed expressly for such use, and were considered at the time to be remarkably light and powerful. The motor, which was designed with the assistance of M. Gramme, weighed 220·5 pounds, and developed nine horse-power. The battery was the result of the researches of Renard himself. "The great total energy of

this battery," Mr. Soreau tells us, "is due principally to the substitution of chromic acid for the bichromate, whose alkaline base absorbs, in reaction, a portion of the exciting liquid. Its capacity reaches its maximum when the weight of the chromic acid is equal to five-sixths that of the hydrogen acids. Then fifty-five watts per square decimeter per hour is obtained. The rate of current is obtained by the partial or total substitution of hydrochloric acid for sulphuric acid in the bichromate batteries; the total energy of the mixture does not change, but the energy per second increases with hydrochloric acid, and can be quintupled."

Having made a careful study of the best geometrical arrangement of the parts of the cell Renard found that this battery would deliver to the shaft one horse-power for each eighty-eight pounds of its weight.

It may be interesting to compare the capacities of the various motors thus far employed for aëronautical purposes. Giffard's steam engine and boiler taken together, without fuel or water, weighed, according to his own report of September, 1852, 110 pounds per horse-power. The electric motor used by the Tissandier Brothers, which derived its current from a bichromate of soda battery, weighed, together with the battery and sufficient liquid for two-and-a-half hours' work, a little more than 330·6 pounds per horse-power.

The electric motor and battery used by Renard weighed, as shown by the data given above, about 112·7 pounds per horse-power; or 130 pounds per horse-power, if equipped to run one and one-half hours.

As we shall see later, these motors are immensely heavier than the steam engines recently constructed for purposes of mechanical flight; but it is understood that electric motors have also been very much reduced in weight since the experiments with La France, in 1884–85. M. Trouvé is said to have constructed an electric motor wound with aluminum wire instead of copper, which weighs but 7·7 pounds per horse-power without the battery. Mr. Soreau informs us, in his excellent memoir read last February before the French Society of Civil Engineers, that the

researches of Renard have led to the invention of an electric motor and battery weighing one-and-one-half times less than the one used in La France, and this with supplies enough to last for twelve hours.

The ascensions of La France in 1884–85, if we regard them as experiments, ought to be considered as extremely successful and encouraging; not that they represented or pointed to the complete achievement of aërial navigation, but because they so far surpassed all previous successes. The balloon moved through the air as steadily as a boat upon the water, and obeyed her rudder perfectly, heading against the wind or at any angle to it, or turning entirely about at the will of the aeronauts. On her first voyage from Chalais she traversed a distance of four-and-one-half miles in twenty minutes, made various evolutions in the air with the greatest ease, and returned to her point of departure. The following account of this voyage is given by Renard: "As soon as we had reached the top of the wooded plateaus which surrounded the valleys of Chalais, we started the screw, and had the satisfaction of seeing the balloon immediately obey it and readily follow every turn of the rudder. We felt that we were absolutely masters of our own movements, and that we could traverse the atmosphere in any direction as easily as a steam launch could make its evolutions on a calm lake. After having accomplished our purpose, we turned our head toward the point of departure and we soon saw it approaching us. The walls of the park of Chalais were passed anew, and our landing appeared at our feet about 1,000 feet below the car. The screw was then slowed down and a pull at the safety-valve started the descent, during which, by means of the propeller and rudder, the balloon was maintained directly over the point where our assistants awaited us. Everything occurred according to our plan, and the car was soon resting quietly on the lawn where our assistants awaited us."

Six other similar voyages were made within the two years following, and we have as a result, that in five out of the seven trials, the balloon returned to its point of departure. Its failure to return in the other two trials was due,

in the one case, to the breaking down of the motor: in the other, to the resistance of a strong wind which made it necessary to land at a distance from the starting point. The last of these remarkable voyages was performed in presence of the Minister of War, on the 23d of September, in 1885. The balloon started from Chalais and sailed against the wind directly to Paris, passed over the fortifications, described a graceful curve and returned to its place of departure, recording an average speed of 14·5 miles an hour.

After these ascensions so little was heard from the laboratory of Chalais that the public began to regard the brilliant voyages of 1884–85 as the final and ultimate possibility of aëronautics, and to believe that Renard's silence was due to a loss of confidence in the navigable war-balloon. He was, however, continuing his researches with great earnestness and with much secrecy, as they were considered to be of importance to the national defence. Finally, about a year ago, it was announced that he was preparing to experiment with a new war-balloon of extraordinary capacity, calculated to attain a speed of 24·8 miles an hour and to operate in the air twelve hours at a time. In exterior figure this balloon will resemble La France; it will measure 230 feet in length, 42½ feet in greatest diameter, and will be propelled by a screw about 30 feet in diameter. With this vessel it will, therefore, be possible to execute a journey of 300 miles between dawn and dark without the aid of the wind and without halting for supplies.

After this balloon has been tested others will doubtless follow in proportion to the efficiency manifested and the probable demand for such instruments of war.

We naturally inquire: What will be the ultimate speed and use of the navigable balloon? And this is, at present, an open question. There are enthusiasts who argue that speeds of forty to fifty miles an hour may be attained, and that, therefore, the air-ship may find a variety of commercial uses. I may mention that Giffard, after the success of his first experiments, prepared the plans of a mammoth vessel which was to be propelled at a speed of forty-four

miles an hour, even with the engines he could then command. So confident was he indeed, that he obtained a patent for, and means to venture the expense of constructing a balloon nearly two thousand feet long—a work he would undoubtedly have attempted had not blindness overtaken and prevented him. Since his day a variety of similar proposals have been made. Some inventors have advocated constructing gigantic vessels of aluminum, or steel, upon the covering of which the propellers should be planted so as to exert their united pull in the line of resistance, and we should not be surprised if some daring engineer should one day attempt some such ambitious construction. On the other hand the more prudent engineers contend that speeds above thirty to thirty-five miles an hour are impossible, or, if physically possible, that the enormous power required, the frailness of the envelope, the cost of housing and repairs, and the scant carrying capacity, would render the air-ship forever impracticable for commercial purposes.

In this speculation it is interesting to observe that the navigable balloon does not fail for lack of strength to endure high velocities or surging storms, for it may be shown by very simple calculation that a large hull made of fabric, or metal, and inflated under pressure, may be made amply strong enough to withstand a velocity through the air of fifty to sixty miles an hour, if the propulsive force be well distributed. I desire especially to direct your attention to this fact, because some of the most eminent advocates of flying-machines have asserted that balloons could not be made strong enough to endure any considerable speed. It may be added also that it is physically possible with our present light motors to propel a large balloon at a speed of fifty to sixty miles an hour, though I would not for a moment assert that it is mechanically practicable.

To prepare the dirigible balloon to run at high velocities, it will be necessary to keep it continuously rigid, and to locate the propellers near the centre of resistance. The first of these requirements can be fulfilled by inflating it under pressure; the second, by planting the propellers directly on the covering of the vessel. This means that

the envelope should be made of very stout and impervious material, perhaps of metal, and hence, that it should be of titanic proportions. Here, of course, lies the real difficulty; for, while it may be simple enough for a mathematician to indicate the most favorable dimensions for an air-ship of great strength and speed, the realization of his figures may present insuperable bounds to the financier, if not to the mechanician.

Leaving aside the question of finance, which is not usually urged as an objection, let us consider merely the physical possibility of such a construction. Selecting La France as a model, let us estimate the capacity of an air-ship of ten times her linear dimensions. The data we shall require are as follows: length of La France, 165 feet; greatest diameter, 27·5 feet; surface, 10,000 square feet; buoyancy, 4,400 pounds; speed, 12 miles an hour; resistance at 12 miles an hour, 50 pounds. Remembering that the buoyancy of a balloon increases as the cube of its linear extent, while the surface and resistance increase only as the square, we have for a balloon of ten times the linear measurement of La France and moving 12 miles an hour, the following: length, 1,650 feet; greatest diameter, 275 feet; surface, 1,000,000 square feet; buoyancy, 4,400,000 pounds; resistance, 5,000 pounds. The power required to overcome a resistance of 5,000 pounds, 12 miles an hour, allowing an efficiency of 50 per cent. for the screw-propeller, is 320 horse-power, which, if supplied by a motor of Mr. Maxim's design, would imply a weight of only 3,200 pounds. Suppose the motor to weigh 400,000 pounds, or 125 times the weight above found necessary; it will then be competent to propel the balloon sixty miles an hour, and still leave 4,000,000 pounds surplus buoyancy. We thus see that a motor fit to carry a flying-machine will also propel a balloon at a high rate of speed.

We have next to inquire whether the vessel can be made strong enough to support the enormous pressure of the air at this velocity. The resistance of a plane surface moving normally at the rate of sixty miles an hour, is, roughly, eighteen pounds per square foot; and if the internal pres-

sure of the gas can be safely raised to this amount, it is clear that the balloon may be driven a mile a minute without collapsing. Let us allow 2,000,000 pounds for the covering of the balloon. If we construct it of uniform sheet steel, the metal will be .05 of an inch thick and subject to a tensile stress of 4,125 pounds, when the covering is inflated under a pressure of eighteen pounds per square foot. Hence, a steel balloon may easily endure a speed of sixty miles an hour, without danger of collapsing, if it be properly propelled.

A balloon of such strength and inflation would require no net, and both cargo and motors could be supported directly upon the covering. The two million pounds remaining for passengers, cargo and supplies would occupy relatively such small room that the general exterior of the vessel would appear plump and smooth as a whale. There being then no boat, netting or other projecting parts to oppose the progress of the vessel, save the numerous small propellers putting out from its surface, it should move with a relatively less resistence than La France. It would appear from these figures that a balloon competent to carry many hundreds of passengers at speeds rivalling those of the railway train is among the physical possibilities if not commercially practicable. It would afford an interesting exercise to an inventor to work out the details of constructing, housing and repairing such a vessel, of controlling its movements when in use, of inflating it and of preserving its barometric equilibrium. It may be observed that at a speed of thirty miles an hour the power required would be one-eighth as much, and the strain of the vessel one-fourth as much, as at a speed of sixty miles an hour.

ACTIVE AVIATION.

There has naturally been much speculation as to whether we should navigate the heavens in air-ships or flying-machines. From the day of the launching of the first crude Montgolfier there have existed two rival schools of enthusiasts, who, with more acrimony than love, have waged a prophetic contention over the future empire of the illimita-

ble sky. The aëronauts boast of having at least fairly launched themselves while the aviators have not been able to quit the earth. The aviators in turn point to the birds which move with such celerity and ease, while the great gas-bags drift helpless in the currents of the atmosphere. Perhaps ere long it will be discovered that there is room in the sky for both; for certainly each school has plausibly met the objections urged against its propositions.

For a century the odds seemed to be unquestionably all on one side. For just a century, the aëronauts, buoyed up by a subtler element and the hope that springs from partial success, paraded their enormous bags in every land, while the aviators stood pluming their incompetent wings and pointing to the birds as an apology for their own existence. But the century ended ten years ago, and within the past decade the aviators have so far prospered as to dare call themselves even more than rivals on the airy deep.

The remarkable advances of the science of aviation within the past decade, and especially within the past five years, may be chiefly attributed to two great discoveries: (1) That the power required for direct mechanical flight is far less than was formerly estimated; (2) that this power can actually be more than obtained from well designed steam engines.

As to the estimate proposed by various writers for the power exerted in bird-flight, Mr. Maxim gives us the following quaint summary: "Many years ago a mathematician in France wrote a treatise in which he proved that the common goose in flying exerted a force equal to 200 horse-power; another proved that it was only fifty horse-power, and he was followed by still another who proved very much to his own satisfaction that it was only ten horse-power. Later on, another wrote to prove that a goose expends only about one horse-power in flying. At the present time, however, many mathematicians may be found who are ready to prove that only one-tenth part of a horse-power is expended by a goose."

This is evidently an advancement of 200,000 per cent. in favor of human flight. Mr. Maxim, reasoning from the

data of his own carefully conducted experiments, would reduce even this last figure. "The goose would," says he, "exert no more than ·083 of a horse-power, which is rather more than a man power, and is at the rate of 144·5 pounds per horse-power."

At the International Congress of Aëronauts and Aviators, held at Paris, in 1889, two papers were read, one by Mr. Drzewieki, a Russian engineer, and the other by Mr. Chanute, of Chicago, which presented some new and more encouraging views of the requirements of flight than had formerly prevailed. Mr. Drzewieki, insisting that the bird's wing during rapid flight performs the role of both a screw and an aëroplane—that is to say, that the outer quill feathers pull the bird forward, while those near the body sustain it by their continuous gliding action—estimated, by the aid of empirical formulæ, the various resistances to forward progression encountered by the bird and the powers expended in overcoming them at various velocities and angles of flight. As a result, he concluded that the most favorable angle of flight, or that of minimum resistance, is 1° 50′ 45″, an estimate which agreed very closely with that obtained by Mr. Chanute from a theoretical analysis. Mr. Drzewieki then calculated the power needed to drive an aëroplane at this angle, assuming that its cross-section, which would offer a hull resistance, should measure one per cent. of its horizontal projection. He gave, as his conclusion, that to carry a burden of one ton including its own weight through the air at a speed of twenty-five miles an hour, would require 5·87 horse-power.

Mr. Chanute's investigation of the power expended by the common pigeon flying at this velocity and with its much greater proportion of hull resistance, lead him to believe that an equally efficient large machine would need 10·49 horse-power to carry one ton at a speed of twenty-five miles an hour.

These were encouraging figures, surely, and they seemed to be well corroborated by the systematic investigations of both Mr. Maxim, of England, and Dr. Langley, of the Smithsonian Institution. After a long series of delicate measure-

ments of the carrying capacity of inclined planes gliding on the air at various angles and velocities, Langley informs us that one horse-power, properly applied to the propulsion of an aëroplane, may sustain fully 200 pounds and upwards. Maxim, who experimented with much larger planes, concludes that certainly as much as 133 pounds may be sustained by the expenditure of one horse-power (13'53 horse-power per ton), and under certain conditions as much as 250 pounds.

These conclusions refer only to simple plane surfaces, and it is desirable to learn what corrections to make for an actual flying machine offering a hull resistance. We fortunately have some data furnished by practical trials. Mr. Tatin, of France, informs us that his aëroplane sustained 110 pounds per horse-power; Mr. Phillips, of England, records 72 pounds; and Mr. Hargrave, of Australia, as much as 89 pounds per horse-power. Mr. Chanute, in concluding his exhaustive articles in the *American Engineer*, expresses his belief that 45 pounds per horse-power may be supported in practice by the direct action of a screw, or 100 pounds per horse-power by means either of flapping wings, or by means of an aëroplane urged by a screw. He has also inquired what proportion of the entire weight sustained may be devoted to the motor in a machine large enough to carry one man. He presents us his conclusions in the following interesting table:

Kind of Apparatus.	Pounds Sustained per H. P.	Proportion Available for Motor.	Resulting Possible Weight of Motor per H. P.
Screws	45	⅓	15
Wings	100	¼	25
Aëroplanes	100	½	50

With these figures before us we may glance at the list of the various motors that have been employed for purposes of aërial navigation and see how nearly they have met these requirements. In the first rude essays at human flight the only available source of power was that of the human

muscle, which meant at least a thousand pounds per horse-power, if continued for any length of time. Giffard's boiler and engine without supplies weighed, as we have seen, 110 pounds per horse-power, Tissandier's motor and battery 330·6 pounds, Renard's motor and battery, according to the most favorable and latest reports, 66 pounds. Evidently these were all too heavy. Mr. Stringfellow's famous little steam engine and boiler is reported to have exerted one horse-power and to have weighed, without supplies, only 13 pounds. If we allow 25 pounds an hour for fuel and water it would appear, from the above table, that such a motor ought to fly an hour and a half. Its performance, however, did not realize all that was expected of it. It may be remarked in passing that the lighter electric motors of Renard and Trouvé were amply powerful enough to operate a trolley flying machine. It might be suggested also that such a machine would offer the readiest and most economical means of studying the questions of stability and steering, for it would be cheap to construct, and in flying would behave very nearly like a machine in free flight.

Such was the prospect of aviation up to the period of the French Aëronautical Congress of 1889. Not only had men an exaggerated notion of the power required for flight, but they had also only a vague conception of the capabilities of artificial motors. Mr. Stringfellow's little model seemed to represent almost the ultimatum of steam-engines, yet it had not flown successfully. It was declared that artificial motors would have to be made to rival the birds in relative output, an attainment which did not then seem feasible. Indeed, one philosopher, and a well-known American writer, published an article in which he demonstrated in the most eloquent and positive language that such an achievement was absolutely impossible. Nature had tried for centuries to produce a relatively lighter prime-mover than the bird and had failed; it was therefore senseless for man to hope ever to do so.

While scientific and unscientific writers were indulging in these speculations, Mr. Maxim went resolutely to work and

at one step, reduced the weight of the steam engine, with its boiler and condenser, to less than ten pounds per horse-power; and now that he has so completely outstripped nature, who will again look to her as sole mistress? To add to the chagrin of such speculations, Mr. Maxim expresses the belief that a useful working boiler and steam-engine can be constructed to weight but five pounds per horse-power. "I am of the opinion," he writes, "that with a generator and engine especially constructed for lightness, a naphtha motor could be constructed which would develop one hundred actual horse-power and not weigh more than five hundred pounds, including the condenser, and still have a factor of safety quite as large as we find in locomotive practice." These announcements have certainly astonished the scientific and engineering world.

We have since been apprised of the labors of several other inventors which bid fair to rival even Mr. Maxim's achievements. Mr. Phillips of England, has an engine, whose actual power I have not learned, which, with its unique aëroplane, can readily lift itself from the ground and fly forward at a considerable speed. After observing the performances of this machine, Mr. Breary, Secretary of the British Aëronautical Society, wrote me last July that he thought we might "soon throw up our hats." Mr. Mosher, builder of the "Norwood," informed us last August, at the Conference on Aërial Navigation, that he was prepared to furnish specifications and build aëronautical engines for experimental purposes that should weigh no more than ten pounds per horse-power. Mr. Hargrave informed us, in a paper contributed to the same conference, that he had constructed an engine and boiler which, with twenty-one ounces of fuel and water, weighed but seven pounds and developed 0·653 of a horse-power, or at the rate of one horse-power for 10·7 pounds of total weight. He states that his present construction is cheap and simple and that he sees how it may be considerably reduced in weight. The copper tubing of his boiler, for example, which weighs thirty-seven ounces may be reduced to eight ounces and still be abundantly strong, while at the same time retaining its evaporative capacity.

It may be interesting here to make an observation regarding the design of aëronautical boilers. It can be proved that if one pound of copper be drawn into a long boiler tube, capable of resisting a given pressure, the solid contents of the tube will be the same, however small its diameter may be. It can be shown, also, that if two such tubes have equal weight, equal interior capacity and bursting strength, but unequal diameters, their convex surfaces, that is to say, their evaporative powers, will be inversely as the diameters of the tubes. From this it would appear that a boiler composed, for example, of quarter-inch tubes, would possess sixteen times as much heating surface and, consequently, sixteen times as much evaporative power, as a boiler of equal weight made of four-inch tubes. It may be added also, that the total space occupied by the tubes of each boiler, would be equal if the relative arrangement were the same; and that, as the diameter of the tubes became indefinitely small, the heating surface would become indefinitely great.

But this is a digression. When the power required for direct flight had been determined with some degree of accuracy, and the motors capable of supplying such power were an assured reality, the attention of engineers was especially directed by several writers to another remarkable fact, which, so far as I am aware, was first proved by A. Du Roy de Bruignac, and, in 1875, formally enunciated by him, in the following words: "Providing the angle of a heavy plane, moving in the air, be maintained at the minimum necessary to sustain its weight, the work of translation diminishes as the velocity increases." Mr. Chanute, in his recent book on aviation, p. 43, shows that this statement may also be applied to birds and flying-machines moving at limited speeds, say of thirty to forty miles an hour. He further shows, in his little pamphlet on Aërial Navigation, published by the *American Engineer*, that to carry a ton of weight through the air at these speeds on a flying-machine, would require very much less power than to carry the same in the best navigable balloon thus far designed.

These are surely formidable arguments in favor of me-

chanical flight, and it is not strange that they should excite hope. It is not surprising that the final decade of the century should witness extraordinary and perhaps final efforts to ride the air on expanded wings. When we remember that at the Aëronautical Conference of 1889 men were just beginning to see their way clearly, while at the Conference of 1893 they were discussing full-fledged machines of excellent promise, we may not unreasonably hope that at the Paris Conference of 1900 we may be offered printed excursion tickets for actual flights through the air. The attraction ought surely to equal that of a tower or of a great revolving wheel.

Since the beginning of the year 1890 a great number of elaborate experiments with flying-machines have been announced, some of which we may briefly notice here; the most promising of these being the experiments of Mr. Maxim and of Mr. Phillips in England and of Mr. Hargrave in Australia.

Mr Maxim's machine looks not unlike a locomotive rigidly suspended by small rods from a great kite which it drives forward by the aid of a pair of large horizontal screws. The following particulars of it are taken from Mr. Maxim's description in the *New York Sun* for May, 1890: "My large apparatus is provided with a plane 110 feet long and 40 feet wide, made of a frame of steel tubes covered with silk, Other smaller planes attached to this make up a surface of 5,500 square feet. There is one great central plane, and to this are hinged various other planes, very much smaller, which are used for keeping the equilibrium correct, and for keeping the flying-machine at a fixed angle in the air. The whole apparatus, including the steering gear, is 145 feet long. A part of the aëroplane, or actual kite, is made of very thin metal, and serves as a very efficient condenser for the steam.

"It is ready and awaiting my return. It is now resting on a track eight feet wide and half a mile long, in my park. The first quarter of a mile of the track is double—that is to say the upper track is three inches above the lower one. By that means I am able to observe and measure the lift of the ma-

chine when it starts, because the upper track will hold it down when it lifts off the lower one. When completed the machine will weigh, with water, tanks and fuel, somewhere between 5,000 pounds and 6,000 pounds, and the power at my disposal will be 300 horse-power in case I wish to use it: but it is expected that about forty horse-power will suffice after the machine has once been started, and that the consumption of fuel will be from forty pounds to fifty pounds per hour. The machine is made with its present great length so as to give a man time to think; its length makes it easier to steer and to change its angle in the air. Its quantity of power is so enormously great in proportion to its weight that it will quickly get its speed. It will rise in the air like a sea-gull if the engine be run at full speed while the machine is held fast to the track; and if it is then suddenly loosened and let go."

In an article published in the *Century Magazine* for October, in 1891, Mr. Maxim gives us some description of his engines and boiler. "I have come to the conclusion," he says, "that the greatest amount of force with the minimum amount of weight, can be obtained from a high pressure compound steam engine, using steam at a pressure of from 200 pounds to 350 pounds to the square inch, and lately I have constructed two such engines, each weighing 330 pounds. . . . . These engines are made throughout of tempered steel, and are of great strength and lightness (and designed to yield 300 horse-power). The new feature about my motors, however, is the manner of generating steam. The steam generator itself, without the casing about it, weighs only 350 pounds. It is self-regulating, has 48,000 brazed joints, and is heated by 45,000 jets, gas being made by a simple process from petroleum. When the machine is finished the exhaust steam will be condensed by an atmospheric condenser, and made of a great number of thin metallic tubes arranged in such a manner that they form a considerable portion of the lifting surface of the aëroplane. The greater part of the machine is constructed from thin steel tubes. I found that these were much more suitable for the purpose than the much-talked-of aluminum; still I

believe that if I should succeed in constructing a successful machine it would lead to such improvements in the manufacture of aluminum products that it will be possible to reduce greatly the weight of the machine."

In a private letter to Mr. Chanute, October 6, 1892, Mr. Maxim gives some further details which have since been made public in the *American Engineer*. "For fuel," he writes, "I employ naphtha of seventy-two degrees Beaumé. This naphtha is pumped into a small vertical boiler heated with a part of its own contents.

"The vapors from the boiler are led directly to an air injector, where they escape under a pressure of thirty-five pounds per square inch. The mixture of air and gas is then burned through rather more than 6,000 gas jets under the boiler. Steam might be also mixed if required. The distributing of the flame is very even, and it is possible to fill the whole fire-box with a purple flame. With two screws, each 17 feet 10 inches in diameter, and with 300 pounds to the square inch, the machine was made to pull on a dynamometer, 1,960 pounds. If we multiply this pull by the number of turns per minute that the engine makes and by the pitch of the screws we find that the engines develop 300 horse-power.

"The complete weight of engines, boilers, pumps, generators, condensers, and the weight of water in complete circulation, amounts to eight pounds to the horse-power and this of itself I consider quite an achievement. . . . The whole machine is mounted on steel wheels, eight feet gauge, and springs are interposed between the machine and the axle trees; both forward and back axle-trees are attached to a dynamograph, which makes a diagram of the lift of the machine as it advances upon the track. The drum which holds the paper turns once round in 1,800 feet, and whatever the machine lifts either forward or back is recorded upon the paper drum. One of the drums is also provided with a pencil which makes a diagram of the speed at which the machine is traveling."

Mr. Maxim has made frequent trials of his flying-machine at speeds of twenty-five to thirty miles an hour and

reports that it can easily lift itself from the track with the exertion of but half its power. In a test described by him last spring, three men and 500 pounds additional weight were placed on the machine to hold it down; yet at a speed of twenty-five miles an hour the forward part of the machine was raised from the track and the total lift was recorded at 6,000 pounds.

Mr. Maxim complains that he is very much hampered for room and thinks that he should have a circular or oval track at least a mile long. With this advantage he thinks that he could solve the remaining problems of stability and steering so as to launch safely into the air and alight safely. He thinks these experiments would occupy him about two years and cost $50,000 to $100,000.

[*To be concluded.*]

ENGINEERING PRACTICE AND EDUCATION.

By Gaetano Lanza, S. B., C. & M. E.,
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[*Continued from p. 227.*]

It is no longer necessary to undertake to answer the arguments of those who take the ground that a proper mental training, and hence, a proper education, is only to be attained through the pursuit of classical and literary studies; and that the tendency of a course of study which deals with science and the applications of science to the industrial work of the world, is to exercise a narrowing rather than a broadening influence upon the student, unless it be preceded or accompanied by a classical and literary course.

This matter has been the subject of a vast amount of discussion, especially among professional educators, and among those who devote a good deal of time and thought to a study of different systems of education and their effects,

particularly as regards the mental development of the pupil.

It is now generally, if not universally, admitted that, not only can a good mental training be attained by a variety of different courses of study, but also that in order to give to any individual the best mental training possible for him, and hence the best education, the course which he should pursue should depend upon what is variously termed his natural aptitude, his bent, or what he has a taste for; and that if the course of study which he is made to pursue is a different one, his mental training, and hence his education, will be more or less successful in proportion as it is less or more removed from the course which is suited to his natural aptitude.

It is the stage of educational progress marked by the evolution of this idea that has caused our colleges and universities to do away with one fixed curriculum, and to introduce the elective system, *i. e.*, a system of elective studies or elective courses; and so completely has this degree of progress been attained, that the number of colleges that still adhere to one fixed curriculum is very small.

The next stage of educational progress is marked by the evolution of the idea that scientific study, and the study of science as applied to the industrial work of the world, is fully capable of giving the very best mental development to those whose aptitude lies in that direction; and this idea is now very generally conceded, although it had to have a hard fight to gain its position, and there are still a few remaining who oppose it.

The degree of success achieved by the advocates of the new education may best be judged by the enormous development which has taken place in the last twenty or twenty-five years in the scientific and technological schools of the country. Not only has the number of such schools increased very largely, but the increase in the number of pupils in these schools also has been phenomenal. It is thus conclusively proved that there is a very large and rapidly increasing number of persons who choose to give their sons such an education as these schools have to offer, rather than such an education as is offered by the colleges, and who believe

that they are thus giving them a better equipment to meet and deal with the problems of life, under whatever circumstances they may be thrown.

But even more evidence is furnished of the prevalence of the idea by contrasting the character of the courses of study offered, and the equipment of these schools to-day, and their condition in these respects about twenty years ago.

It will be evident to any one who will institute such a comparison, even superficially, that the entire drift of the development of these schools has been in the direction of making them more thoroughly scientific, more thoroughly practical, and more closely in touch with the live questions of the industrial work of the day, and the industrial outlook for the future.

In other words, they tend more and more to concentrate the attention and thought of the student upon those subjects that will fit him best for his life-work, making the extent to which other subjects can be introduced dependent upon the time that can be afforded for them consistently with a thorough performance of the work that forms the main objects of the course.

This tendency is not one started by a few educators, which may be lightly charged with lack of wisdom. It is one which has been irresistibly forced upon the schools by the spirit of the age, and which is in the direct line of progress, and, like all other things that are in the line of progress, it cannot be stopped.

Far be it from me to undervalue a thorough classical or literary education, for those whose natural aptitude lies in that direction, or to dispute the desirability, nay, importance, of giving to the engineering or technical student a certain amount of literary training; but I believe that the foremost and principal object to be accomplished by any system of education is mental training, *i.e.*, the development of the powers of the mind, and that this is far better attained by doing some one line of work thoroughly, than by scattering one's energies over a large field. There is no more effective means of imparting to the young man powers of mental

concentration, and of fitting his mind to grasp and grapple with the serious work of life, than a course of scientific and practical study. The acquisition of this mental power is the principal object of education, and, if this be neglected, the result is shallowness and not education, even though the student may have done more or less reading, and acquired more or less information on a variety of subjects.

If mental training has been neglected in the education of a young man, it is only with the greatest difficulty that he can repair the damage, and acquire mental power later in life, and, moreover, a greater amount of varied information will not compensate for, nor take the place of, the disciplined power of the mind; whereas, if this has been acquired even by the sacrifice of a certain amount of general reading and information, it is far easier to do this reading later.

Hence, when an engineering course is to be laid out, it should be planned as an engineering course, and should aim to accomplish its object of fitting the student to become an engineer in the best and most thorough manner, and then should be added such general studies as will not conflict with a thorough accomplishment of the engineering work; and the fact should be kept constantly in view that it is mainly on the scientific and practical work of the course that reliance is to be placed to impart mental training; and that, although the general studies are very important, and have their educational value, besides serving to give information, the part they play in giving mental training is far less than the part played by the scientific and practical work.

Another matter, which only of late years has received full recognition, is that the training of the hand and eye forms an important factor in all education, and especially so in a scientific and a technical one. The recognition of this fact is due primarily to the development of the study of science, and especially of applied science; for, in order to make such study successful, it is necessary that the student should observe and experiment, and thus ask questions of nature, and then understand how to interpret correctly her replies.

Thus, the performance of chemical laboratory work by the students with their own hands has been carried out for a number of years in the case of those who were fitting themselves to become chemists. The introduction of physical laboratory work, performed by the students themselves, is of much more recent date; but since its introduction it has been adopted to a very considerable extent, and has proved to be one of the best, if not the very best, means of training the student to perform experimental work with accuracy and thoroughness; to observe, note and collate the facts as they occur; to make measurements with great precision, and to understand and appreciate what are the sources of error that are inevitable, and what are the limits within which the conclusions can be assumed to be correct. The introduction of laboratory practice into the teaching of natural history, of chemistry and of physics constitute a great advance over former methods of teaching science.

But of late years other advances which have been made have exerted a most important influence on technical, and especially on engineering education, namely, the introduction into engineering courses of study, of practice in engineering laboratories, where the student is taught to perform experimental engineering work on a large scale, and under such conditions as occur in practice, thus putting him in touch with the sort of work he is liable to be called upon to do after he enters his profession. Thus, we find, in connection with engineering schools, laboratories for testing the strength of materials, steam laboratories, hydraulic laboratories, mining laboratories, electrical engineering laboratories, chemical engineering laboratories, etc.; and, although they form a comparatively recent addition to the work of engineering schools, their number, their equipments and their efficiency have increased with surprising rapidity during the last few years, so that now there is hardly a school in the country claiming to teach engineering that does not consider it necessary to make an attempt to establish engineering laboratories of some sort.

The other development referred to is the enormous impetus that has been lately given to manual training.

It is true that in France and Germany there have been established for some time what may be called technical schools, which are in no way engineering schools, but more properly trade schools, and that the influence of these schools has been very beneficial to the manufactures of those countries. But the idea of the manual training school is not that of a trade school, but one where, in addition to some more elementary studies of a general and of a scientific nature, the student is taught the use of tools, the object being to educate his hand and eye, to train his powers of observation, to teach him to do work accurately, and to cause him to understand how materials behave by having actually handled and worked with them. And so general has the idea become of the importance of giving this kind of education to children, that not only have large and successful manual training schools sprung up all over the country, but steps have been taken, and are constantly being taken, to give this kind of instruction in the public schools; so that it has already been introduced in many localities, and is rapidly extending.

Even England has waked up in this matter, and displays far more energy than ever before in founding science schools for younger pupils and for artisans. Now, while the product of the manual training school is not an engineer, and while a very sharp distinction should be drawn between the graduate of a manual training school and the graduate of an engineering school, nevertheless, a thorough drill in the use of tools is a matter that the engineer cannot afford to neglect. It develops in him a familiarity with the behavior of materials, which he cannot acquire as well in any other way; it gives him a knowledge of how the actual work must be done, and of what is good and what is poor work; it enables him to know how any piece of work should be carried out, and to judge whether it is satisfactory or will be so when it is finished; so that the instruction given through actual work with tools in the shop is a matter which, unless it has already been taught in the preparatory school, should receive its fair share of attention in an engineering course, although it is not the most important element.

Moreover, all the recent impetus given to a proper training of the hand and eye as an important educational factor, whether it finds expression in the laboratory, in the workshop, in the manual training school, or even in the trade school, is fast removing whatever remnants of prejudice still exist which would cause hand-work to be regarded as degrading, and instead, the world is coming to the conclusion that it is necessary to a proper education, and, hence, honorable in every way, and also that an education is not complete that does not introduce hand-work at some stage.

Whereas the student of engineering of former times found the only courses open to him in the schools that tended to fit him for his profession were such as could be acquired by studying books and listening to lectures, and while he found that books of pure mathematics had been developed to a considerable extent, he found also a great paucity of books that treated in a thoroughly scientific manner of the applications of science to the practice of the profession he desired to enter; the student of to-day finds a far larger supply of books that deal with the live questions of engineering, besides a very extensive and valuable periodical literature, and, as additional advantages, he finds workshops and laboratories of all kinds open to him, opportunities far greater than ever took shape in the wildest dreams of the engineering student of former times.

So rapid has been the increase in the facilities furnished by these laboratories since they began to exist, and so great is the rate at which their scope and material equipment is increasing, that no limit can be set beyond which their development may not carry them, and we may expect them to progress further and further, ever bringing our engineering courses more and more into touch with the live problems of the day, and reacting ever more and more upon the character of the theoretical portion of the instruction by furnishing it with an ever wider basis of experimentally ascertained and experimentally verified fact upon which to build, and thus developing greater and greater opportunities for the education of the young man; and, inasmuch as the law of nature is a constant growth and development, so must

these opportunities be ever on the increase, so long as engineering work shall be required by the inhabitants of the world. The foregoing remarks furnish, in an exceedingly brief and general way, a view of the opportunities that can be taken advantage of; and, therefore, the question which presents itself to us, in view of all these possibilities, is, what is, all things considered, the best course of instruction to give a young man who is to make some kind of engineering his life work?

And, first of all, shall we make a more successful man of him by taking advantage of these opportunities, or by merely teaching him to read, write and cipher, and, perhaps, to draw a little, and then, setting him to work in the field, in the shop, or in the draughting-room, to make his own way as our grandfathers did, only rising to higher engineering functions through, and after having fulfilled a long course of practice in the lower, which course sometimes might be called apprenticeship, and sometimes had in it hardly enough of the element of instruction to deserve that name? In other words, shall we undertake to teach him first the scientific principles upon which his life work is based, and then set him to work at it, beginning, of course, at the lowest round of the ladder, or shall we leave him to gain whatever knowledge of principles he may acquire by experience and hard knocks, and only learn to avoid failures by first making them, or else by picking up slowly and laboriously, and in a disconnected way such bits of scientific knowledge as he can at odd moments, stolen from a day full of cares, of anxieties and of business? That a number of the most brilliant stars in the galaxy of the world's greatest engineers have been obliged to follow the latter course, and that in spite of it they have achieved the very highest success and renown, is not to be denied; and they deserve all the greater credit and the higher encomiums for having accomplished all that they did under such adverse circumstances; but I believe that almost, if not entirely, without exception, they would agree that the work they could have accomplished would have been even grander had they had greater educational advantages of a scientific and practical nature

in youth, and that they would have saved a great deal of time and hard work if they had been taught early the experience of the past, and the scientific principles and facts of nature so far as they were known at the time, instead of having to steal time from their all-absorbing occupations to pick them up little by little.

I am fully aware of the fact that discussion after discussion has taken place upon this subject, and argument after argument has been advanced both for and against each of these methods of preparing a young man to take up the profession of engineering. To undertake an enumeration of all the discussions that have been held, or of all the arguments that have been put forward, would be an endless task, and I shall not weary you with any such attempt.

It is true that a great many of these arguments are wholly irrational and unworthy of consideration. But we should be careful, in considering them, to do so in a judicial spirit, and not to stamp as wholly irrational everything that is put forward against our own views, and as wholly reasonable all arguments advanced in their favor.

What we ought rather to do, is to begin by separating and laying on one side all the arguments that are wholly absurd and irrational and unworthy of consideration, and then to take up and weigh carefully those advanced by persons who are capable of serious thought, and who have such experience or knowledge of the facts as entitle them to have an opinion on the subject, and who have, therefore, some real or imagined reason, or some partial reason for the arguments which they advance.

Devoting our attention to these, we should endeavor to put ourselves into such a frame of mind that we can realize and understand what are the facts upon which their authors base their conclusions, and to appreciate the point of view from which they look at these facts, real or supposed; and then we shall be better able to pass judicial judgment upon the questions whether their assumed facts really exist, whether they are such as existed at one time and have ceased to exist now, and whether their conclusions are correctly drawn from their observed facts.

That there have been many, and are still a few, men of experience, and of at least fair intelligence, who have taken ground against an education in a scientific school as a preparation for an engineering profession, is a fact not to be denied; but it is also a fact that any such opposition on the part of the experienced and intelligent portion of the community is far less to-day than it formerly was, and what little opposition there is left is fast disappearing, and changing to hearty approval.

In trying to analyze the discussions and arguments against engineering education, we may attempt a certain crude classification, as follows:

(1) There are those who proceed from ignorance and prejudice, and the phases of this ignorance and this prejudice are so varied that it is only possible to enumerate a few.

(*a*) There is always a good deal of talk about the dignity of labor, and it is true that, in the older state of society, labor was thought to degrade a man, but the reaction from this false position has led to the view taken by some ignorant people that any occupation which involves the use of a man's brain, whether accompanied or not by the use of his hands, is degrading. The difficulty with these people is that they do not understand that manual labor is not by any means the only kind, nor is it the hardest kind of labor; neither do they understand that unskilled or unintelligent manual labor is of far less value in doing the work of the world than manual labor performed with intelligence.

(*b*) There is the stupidity and obstinacy of the man who, having become accustomed to one way of doing a thing, is ready to oppose any scheme or proposition which is liable to lead to the conclusion that some other way may be found better than his, and who is especially opposed to any innovation if proposed by some one who has reasoned it out by the use of scientific principles which the former does not possess.

To this class belong a good many who oppose the use of new and improved machinery. It is needless to say that, inasmuch as the world always progresses, such a position as the above injures most the one who holds it.

(*c*) There is another class who systematically oppose the introduction of labor-saving devices, on the ground that the introduction will diminish the work to be done, and, therefore throw a number of people out of employment. They do not realize that the final result is to provide more time for the workers to accomplish a larger amount in the way of results by their labor; for it is a fact that, as labor-saving machinery has been introduced, the comforts and convenience of the entire community have increased, and the very objectors would be unwilling to put up with only such comforts as were available in olden times when no labor-saving machinery had been introduced.

(2) A certain number look to the past, and because there have been men who, with imperfect means at their command, have achieved success and renown, they believe that the course most conducive to success is to imitate them in all external particulars; and that because they accomplished what they did with little early education, therefore, the young men of to-day will succeed best by having no better education.

They do not realize:

(*a*) that their success was accomplished in spite of difficulties and in the absence of early advantages, and not because of them; and that their spirit of indomitable energy caused them to conquer the difficulties with which they were surrounded, and to utilize to the fullest extent all the advantages that they possessed; and that the same indomitable energy would have led them to utilize to the fullest extent a greater number of advantages had they possessed them.

(*b*) that the world is ever progressing, and that, therefore, the new conditions that arise in consequence of this progress present ever new problems to the engineer to solve, which require a knowledge of the experience of the past, and that the more of this experience, in other words, the more science, the young man is already familiar with, the better will he be prepared to meet and grapple with them.

(3) As a rule, an engineer who has started in life without

an engineering education, especially if he has had a fair degree of success, realizes the importance of such an education, knows that he could have accomplished more if he had had it, and desires that the younger generation should have better advantages, and be better equipped for their start in life than he was for his, knowing that if the sons were not to make more progress than their fathers, the advance of civilization would soon be at an end. Nevertheless, every now and then we find some engineer, usually one who is not very able, who values so highly his own accomplishments that he is willing to set them up as a standard for future generations, and knowing that he has reached this standard, although he had no engineering education, he therefore concludes that neither should they have such an education.

It is unnecessary to say any more to show the utter fallacy of the objections stated above; and when we omit a consideration of these, and proceed to analyze the rest of the arguments that have been advanced, I think we shall find, if we read them carefully, that, as a rule, their authors do not object to an engineering education, and, indeed, deem it very necessary and desirable; but they intend their objections to apply to some specific kind of education, the details of which they deem ill-advised or unsuitable. Indeed, I recently undertook to analyze carefully a long discussion of this sort, in which the author made such a number of careless and even contradictory remarks, that to any one who read only certain of his articles it would appear that he did not believe at all in an engineering education. But I found that, after all, he did express himself elsewhere as fully approving such an education and emphasized its importance, and interpreted what he had said that appeared to contradict this idea as meaning simply an objection to certain features of such a course as he imagined was carried on in some places.

Moreover, we should remember that engineering schools are of comparatively recent growth, and that they have been constantly improving their courses, adapting them more and more to the needs of the student who is to enter the

engineering profession, so that the courses given in these schools to-day are far different from those given twenty years ago, when engineering schools were still in their infancy.

Having disposed of the objections to such a course, it seems hardly necessary to present many more arguments than those already advanced in its favor. So much progress has been made in engineering science, and so great have been the developments and improvements in the ways of doing work, that when an engineer undertakes work of any considerable importance, he is obliged, in order to accomplish it properly, to make use of so many kinds of engineering—and hence to be familiar with the scientific principles governing them—that it has become practically an absolute necessity that if a young man is to enter the engineering profession with any chance of ultimate success, he should start with an engineering education already acquired.

The importance of such an education has been urged over and over again by a host of the most prominent engineers, and in the most positive terms. As an example, I may cite the address made by Sir John Fowler, before the British Institution of Civil Engineers, upon assuming the presidency of that institution in 1866. This address was devoted entirely to the education of the engineer, and it was deemed of so great value and importance that it was reprinted and very widely circulated.

I will quote a few remarks taken here and there from that address. He enumerates some of the most important engineering works which were being carried out or planned at that time, and he says:

"All these works present problems of great interest, and it will require cultivated intelligence, patient investigation, and enlarged experience, to accomplish the task of their satisfactory solution;" and again: "In the solution of these problems, thus rapidly indicated, and in others which could easily be adduced, we may rest perfectly satisfied that the difficulties they present are not to be overcome by a stroke of genius, or by a sudden happy thought, but they must be

worked out patiently by the combination of true engineering principles, ripe experience, and sound judgment."

And, later on, just before he presents his idea of the kind of course he would prescribe, he says:

"We, of the passing generation, have had to acquire our professional knowledge as best we could, often not until it was wanted for immediate use, generally in haste and precariously, and merely to fulfil the purpose of the hour; and, therefore it is, that we earnestly desire for the rising generation those better opportunities and that more systematic training for which in our time no provision had been made, because it was not then so imperatively required."

But the best evidence of the necessity of such an education is the great demand which exists for the services of the graduates of engineering schools to-day. In our own case, *i. e.*, that of the Massachusetts Institute of Technology, notwithstanding the fact that the increase in the numbers of our students during the last few years has been phenomenal, the number of our graduates from year to year does not begin to keep pace with the demand for them, and the heads of the engineering departments are constantly in receipt of a much larger number of requests for them than can be supplied. Also, those who carry on industrial establishments in this country find that it pays them best to have as assistants young men who understand scientific principles, and who are consequently able to take a certain amount of responsibility, and who, therefore, can grapple with an emergency; for, in a live industrial business, emergencies are constantly arising, which can only be met by clear judgment and a knowledge of scientific principles, and the heads of these establishments have less and less use for men who are merely drilled in performing one operation, and know only that; so that this latter class of men are less and less in demand in this country.

In England, the above-stated condition of things is not yet realized, but the facilities for an engineering education are increasing, and there is a constantly increasing sentiment in favor of it. Moreover, the influences at work are such as cannot fail to bring about, before a very great

while, the same condition of things as exists now in America.

The next matter for consideration is the nature of the course of study that should be pursued by the prospective engineer. In the preceding lectures I have enumerated and described a variety of engineering industries and of establishments where engineering formed at least a large part, and often the greater part, of the work to be done. The cases cited furnish examples of a number of kinds of engineering, commonly defined by the qualifying words civil, mechanical, mining, metallurgical, electrical and chemical, and perhaps some other industrial operations which are not usually classed with engineering.

If we analyze carefully the work to be done in all of them, we shall find that in many, and I might almost say in all, there are, first, certain processes to be carried out in order to manufacture the desired products, as, for instance, the various processes of melting, filtering, decolorizing, drying and granulating, through which sugar must be carried in a sugar refinery; the series of chemical processes to be pursued in making soaps or glycerine; the metallurgical processes necessary in the manufacture of steel—the proper mixtures of ores, fuel and flux, the proper furnace treatment, etc. Second, we shall find that attention must be given to devising and preparing the means for carrying on these processes efficiently and cheaply; such as designing and building suitable furnaces, machinery, etc.; not solely for the purpose of carrying on the process, but also for a proper and economical handling, so that as little labor as possible may be necessary in receiving the raw materials at the works, in transporting that which has just completed one process to the place where it is to undergo the next, and in getting the finished product out of the works to the consumer or to the market.

This matter of economical handling is one of the most important items about a manufactory, and involves a careful consideration of the proper arrangement of the machinery in the works.

Then arise the questions respecting the best kinds of

machinery to use for all the steps in the process, including a consideration of its efficiency, durability, first cost, the expenses necessary for attendance, also for its maintenance and repair; the expenses necessary for labor in the performance of the several processes, including the labor of handling, of loading and unloading, of transporting, etc.

Next comes the consideration of the nature, construction and arrangement of the power plant, whether water or steam power, or both, are to be used. If the former, the proper constructions, such as dams, canals, locks, etc., to bring the water to the wheels, and to discharge it when it leaves them, proper wheel-house, and selection of wheels.

If steam is to be used, the choice of the kind of engine, whether there shall be one or more, and where it or they shall be located, depend upon the character of the work to be done and the uses for steam in the works.

All these matters must be carefully considered with a view to efficiency and economy in the long run. The selection of boilers, the erection of chimneys, boiler-house, engine-house, etc., are all important questions.

Then comes the construction and arrangement of the whole power plant; and next, a consideration of the proper system of transmitting the power from the various sources of power to the different points in the works where it is to be used, whether by shafting, gearing, belting, cotton or manilla ropes, wire ropes or electric dynamos and motors.

Then we shall have to determine the proper design and construction of buildings adapted for the work, including proper foundations for them, proper water supply, proper drainage, proper heating and ventilation, proper light in daytime and when daylight is either not available or not available in sufficient quantity, fire protection, as well as a large number of questions of a similar character, all of which are generally recognized as engineering questions, and of which it would be almost impossible to give a complete list.

In the infancy of manufactures the processes are liable to be the all-absorbing problems, *i. e.*, by what processes to produce the required result; but as any one of these manu-

facturing interests develops, the processes become more or less a settled thing, or, at most, the opportunities for variation from one fixed method are few, and all manufacturers have to conform more or less closely to this fixed method.

When this state of things is reached, the manufacturer who would succeed is forced to pay attention to the engineering problems that arise in his business; and a failure to solve these problems satisfactorily results in very serious loss to the concern, and may more than eat up all the profits.

If, in view of all the above, we were to attempt to define the different kinds of engineering previously referred to, viz.: civil, mechanical, mining, metallurgical, electrical and chemical engineering, and to designate certain kinds of engineering work as belonging to one or the other of these professions exclusively, we should find that, after all, there is no dividing line between them and that much of the work is common to all of them. Hence, these distinctions, so far as they refer to a classification of engineering work, are purely artificial. Moreover, a man cannot be a successful mining engineer, a successful metallurgical engineer, a successful electrical engineer, or a successful chemical engineer, unless he is an engineer well versed in the science and practice of engineering.

We might then define the mining engineer as the man who performs the engineering work in any of the mining industries; the metallurgical engineer as one who performs the same duties for a metallurgical works, and so on.

The mining engineer, in order to be able to do his work properly, must be versed in the processes to be followed in mining operations, otherwise he will fail to appreciate what are the objects to be accomplished, and hence he will not properly adapt his engineering work to the required ends; and so, also, in the cases of the other kinds of engineers mentioned.

Hence, the mining, the metallurgical, the electrical, or the chemical engineer must be, primarily, an engineer, but he must also be sufficiently versed in the special mining,

metallurgical, electrical or chemical processes, to be able to adapt his engineering work to their needs.

When we come to the terms civil engineering and mechanical engineering, both of which, at different times have been used in different senses, and both of which have often been used to denote the engineer as I have described him, it is impossible to draw a line, and to assert that any one set of engineering operations belongs exclusively to the civil or to the mechanical engineering profession. Indeed, the term civil engineer has been used at different times to denote all grades, from the thoroughly equipped engineer to the mere surveyor, who knows no engineering at all. Hence, it would not be worth while to attempt to give the various definitions that have been proposed for a civil and for a mechanical engineer. So various and arbitrary have been these distinctions that, according to some, the building of wooden ships belonged to the civil, and that of iron ships to the mechanical engineering profession.

According to the ideas at the present time, generally prevalent among those who make a distinction between the two, it may be said that the work of the civil engineer is associated with the design and erection of what might roughly be called public works, as roads, railroads, bridges, canals, improvements of rivers and estuaries, lighthouses, water supply, sewerage, irrigation, etc.; and that the work of the mechanical engineer is that of dealing with machinery. Hence, the person who had charge of and performed the engineering work for machine shops, for cotton mills, woollen mills, silk mills, flour mills, rolling mills, metallurgical works, manufactories of steam engines of all sorts, whether stationary, marine or locomotive, manufactories of all sorts of machinery, chemical manufactories, motive power and rolling stock departments of railroads, etc., would be called a mechanical engineer.

If, however, we should adopt these as definitions, and proceed to determine the kinds of work which each one would be liable to be called upon to perform, we should find no class of engineering problems that would not probably arise in the work of either the civil, or the mechanical

engineer. To illustrate, take the case of the Forth bridge. You will remember that very large machine shops had to be planned, built and operated; that enormous amounts of machinery had to be used; that a very large portion of it was special machinery, which had to be specially designed and built, and operated under very peculiar circumstances. There were required a number of power plants, including steam engines, steam boilers, etc., all of which had to be built and operated; compressed air had to be produced and used in very large quantities; electric light plants had to be established and operated; a large number of cranes had to be built and operated by power; and an enormous amount of engineering work had to be performed, which, if one attempted to make a distinction, would usually be classed as mechanical rather than civil engineering, and it would be at least a question whether it was not more than the remainder of the work. In the case of bridge work generally, we should find the same condition of things existing in different degrees, according to the circumstances of each case.

Next, if we take up the subject of foundations and of drainage, which usually would be considered as pertaining strictly to the province of civil engineering, we shall find at once that the man who has charge of the engineering work of almost any large manufactory is frequently liable to have to put in a foundation, and every now and then it is a difficult one, to be built to support very heavy loads, and he may even be called on to build foundations under water, as, for instance, when the structure is on the water's edge, or on the shore, and where suitable works must be built to allow vessels to approach it to discharge or to take on their cargoes.

From what has been said it seems to me clear that no line can be drawn which marks off the work of the civil from that of the mechanical engineer, and that the kinds of problems which both are liable to have to solve are largely the same.

[*To be continued.*]

SOME RECENT CONTRIBUTIONS TO OUR KNOWLEDGE OF METALLIC REDUCING AGENTS.*

By H. F. Keller.

In the extraction of metals from their oxygen compounds, carbon is certainly the most important and useful reducing agent. Its great affinity for oxygen is utilized in the manufacture of iron and steel; the commercial production of other useful metals such as copper, lead, zinc and tin is accomplished, either directly or indirectly, with its aid; and under its influence even the energetic metals of the alkalies release their powerful grip upon oxygen. Contrasted with this the use of other substances for the purpose of abstracting oxygen is almost insignificant. Is it surprising, therefore, that carbon is looked upon as the reducing agent *par excellence*, or that the very idea of reduction seems to us inseparably associated with this element?

But the reducing power of a substance, depends in a large measure upon temperature. It is well known to chemists that, under certain conditions, many metals have affinities which are far more powerful than those of carbon. When we glance over the pages of our chemical text books, we see described there numerous experiments based upon the superior combining power of iron, aluminum, zinc, magnesium and the alkali metals. The great Swedish chemist who arranged the elements according to their supposed affinities in an electro-chemical series, was among the first to employ the positive alkali-metals for isolating and preparing other elements. His method consisted in decomposing the halogen compounds by means of potassium; and it was subsequently improved by Berzelius' distinguished disciple, Wöhler. With its aid the latter chemist not only succeeded in reducing for the first time those

* Read at the stated meeting of the Chemical Section, held January 16, 1894.

remarkable metals aluminum and beryllium, but he also showed that *all* those metals, the oxides of which cannot be reduced by either carbon or hydrogen, may be obtained by the action of potassium upon their halogen compounds.

It must not be supposed, however, that the use of metals as reducing agents is confined to the laboratory and the lecture table. Practical applications of such reactions may be less conspicuous, but they constitute, nevertheless, the basis of not a few important metallurgical processes. The "precipitation" of lead from its sulphide ores; the solution of silver by the nascent lead in the blast furnace; the amalgamation of the same metal in the iron pan; Deville's process of extracting "silver out of clay," recently so greatly perfected by Castner and Netto—are they not essentially reductions by means of metals?

In view of the facts mentioned, it may appear strange that comparatively little progress was made for many years in the study of the reducing properties of metals. We can, however, satisfactorily account for this when we consider the great tendency of metals to form alloys; it is difficult, in many cases indeed impossible, to obtain products entirely free from the reducing metal, and it is also well known that even a trifling amount of such impurity may seriously impair the valuable qualities of a metal. Another obstacle has been the high price of those metals, which, by reason of their more powerful affinities, could with advantage be substituted for carbon.

Recent improvements in the commercial production of some of these metals have partially removed the latter obstacle. Thanks to the rapid progress of electro-metallurgy, aluminum is now to be had for about half a dollar per pound; sodium, once a chemical curiosity, is manufactured on an enormous scale at a less cost even than aluminum; and magnesium now, successfully extracted from carnallite is, applied to a variety of technical uses.

The radical changes which have taken place in our views on chemical affinity as a result of the study of thermo-chemical phenomena, and the theory that the properties of the elements are *periodic functions* of their atomic weights,

have also largely contributed to awaken interest and activity in the subject of our discussion.

The remarkably high heats of formation of its oxide and chloride, as well as the great stability of these compounds, render the action of magnesium upon other oxides and chlorides particularly interesting. Clemens Winkler, of Freiberg, has presented us with a most careful and systematic investigation of the reducing action of this metal upon oxides, while Seubert and Schmidt have communicated a similar exhaustive study of its action upon chlorides.

In giving a brief résumé of the results obtained by these experimenters, I shall adhere to the order adopted by them. It is based upon the periodic system, and has the advantage of showing many interesting relations that might otherwise escape notice.

GROUP I.

Group I embraces a main group consisting of Li, Na, K, Rb, Cs, and a sub-group consisting of Cu, Ag, Au.

Owing to the difficulty of obtaining the oxides of the alkali metals in a pure condition, the carbonates were employed. It was found that to insure the best results three atoms of magnesium are required for every molecule of the carbonate, thus: $Na_2CO_3 + 3\,Mg = 3\,Mg\,O + C + 2Na$.

The carbon as well as the sodium are deprived of their oxygen. It was found that, with the exception of Cs_2CO_3, the alkaline carbonates *suffer reduction* to the metallic state when heated with Mg, but that the intensity of the reaction diminishes as the atomic weight of the metal increases. Li, *e. g.*, whose atomic weight is only seven, was reduced with explosive violence, the metal being completely vaporized, while the tube in which the reduction was effected was shattered to pieces; potassium (at. weight 39), and rubidium (at. weight 85) on the other hand, were reduced quickly and without notable vaporization.

The reduction may be made in a tube of hard glass closed at one end; it is better observed, however, by conducting it in a current of hydrogen.

The preparation of potassium affords a most instructive experiment, which may well serve for lecture demonstration.

Into a wide tube of Bohemian glass, a porcelain boat, containing about two grams of the mixture of K_2CO_3 and Mg is introduced. A current of perfectly dry hydrogen gas is passed through the tube, and the part of the tube surrounding the boat is gradually heated to incipient redness; the mass darkens, and upon further raising the temperature with the aid of the blast lamp, the reduced potassium is completely expelled from the boat, exhibiting the deep green color of the vapor, and is deposited in the form of a bright mirror in the cooler part of the tube. At the same time the hydrogen flame shows an intense violet color. The dark residue remaining in the boat consists of magnesia and carbon. Enough potassium will have collected to show its color, lustre; that it is sectile, fusible; its action upon water, bromine, etc.

In view of the high price of metallic potassium, the question as to whether the described reaction might not be carried out on the large scale suggested itself. Experiments showed, however, that in the absence of a gas current, the distillation of the metal is very incomplete; and inasmuch as carbon monoxide forms an explosive compound with this metal, illuminating gas could not be substituted; in fact, the explosive carbonyl-potassium was invariably formed when the quantity of magnesium present was insufficient for the *complete* reduction of the carbonate.

This was further proved by experiment. When two atoms only of Mg were taken, the reaction took place according to the equation:

$$CO\begin{matrix}OK\\OK\end{matrix} + 2\,Mg = CO + 2\,K + 2\,MgO.$$

More promising results were obtained by employing KOH instead of K_2CO_3. The danger of forming the explosive body is thus avoided, while the H gas set free simultaneously with the K, ensures the complete distillation of the latter.

$$KOH + Mg = K + H + MgO.$$

The reaction is somewhat violent, but may be moderated by adding some inert substance, such as magnesia; or by using the magnesium in the form of lumps or bars.

Winkler says "it does not seem unlikely that the manufacture of potassium could be carried out by means of the same apparatus, and the same operations, which C. Netto has so successfully employed in reducing caustic soda with carbon. Into a retort filled with bars of magnesium, and heated to redness, melted potash would be allowed to flow in a continuous stream, while the escaping mixture of potassium vapor and hydrogen is being cooled."

Winkler figures the cost of one pound of potassium to be about $3.75; the metal is now quoted at $28.

Beketow, who had previously made use of the action of Al upon KOH, obtained only one-half of the theoretical yield owing to the simultaneous formation $KAlO_2$.

The sub-group consisting of the heavy metals Cu, Ag, and Au exhibited the reverse behavior; the reduction was more energetic the higher the atomic weight of the metal. A very *slight* deflagration accompanied the removal of O from cuprous oxide, while Ag_2O was reduced with *explosive violence*. Very curiously aurous oxide was not visibly affected by the magnesium. This is explained, however, by the fact that Au_2O splits up into its constituents considerably below the ignition point of Mg.

GROUP II.

The main group comprises Be, Mg, Ca, Sr, Ba; and Zn, Cd, Hg, constitute the sub-group.

These elements are divalent, and the action of their oxides upon Mg is therefore:

$$R'' O + Mg = MgO + R''$$

In some cases the *hydroxides* were also used.

Beryllia was easily reduced by Mg; the mass became slightly incandescent, but some unaltered oxide was found in the residue.

There was no action observed when a mixture of Mg and MgO were treated in H; the oxide remained in the boat, while the metal sublimed in beautiful crystals. The existence of Beetz's suboxide could not be confirmed.

No visible sign of chemical action occurred when lime

and Mg were heated together. The reduction proved nevertheless to be almost complete.

A slight incandescence attended the reduction of strontia, whilst oxide of barium displayed an energetic action upon Mg. In both cases the decomposition was apparently complete.

None of the alkaline earth metals were found to be volatile at the temperature of reduction.

The hydroxides were even more readily acted upon than the oxides; so striking and beautiful, indeed, were the phenomena observed in the cases of $Ca(OH)_2$ and $Sr(OH)_2$, that Winkler proposes to utilize them for lecture illustration, and in pyrotechnics.

The reduction of the oxides belonging to the sub-group was very energetic, the resulting metals being vaporized completely. Cadmium oxide develops less energy than either zinc oxide or magnesium oxide.

Both in the main group and the sub-group, the maximum of chemical energy occurs in the second member.

GROUP III.

The main group embraces B, Al, (Sc), Y, La, Yb; Ga, In, Th, form the sub-group. Three atoms of magnesium are required to abstract the oxygen from their oxides:

$$R_2O_3 + 3\ Mg = 3\ Mg\ O + 2K'''$$

Phipson has observed that boric acid is reduced upon ignition with magnesium. With the aid of Mg, boron was also obtained by Geuther from the boro-fluoride of sodium, and quite recently L. Gattermann has shown that boric acid, as well as borax can be reduced by means of this metal, so as to yield products which are suitable for the preparation of various boron compounds.

Winkler confirmed these observations. He states that the trioxide and the borate of sodium are easily reduced, the latter with much energy and evolution of sodium vapor. But he found that, instead of free boron, the residue contains magnesium boride of variable composition; for, on treatment with hydrochloric acid, hydride of boron is given off

as a gas. Sometimes a solid residue remains, which is likewise a compound of boron and hydrogen.

Owing to the acid-forming character of boron, the reduction was never complete; borates, upon which magnesium has no action, are always formed.

An attempt was also made to prepare a sub-oxide of boron by limiting the supply of Mg, thus:

$$B_2O_3 + Mg = 2\,BO + MgO$$

but no indication of such an oxide was observed.

A dark colored product resulted from heating alumina with magnesium. The reaction appeared to be quiteen ergetic; the mass exhibited a vivid glow and increased largely in volume. In addition to finely divided aluminum, a new oxide, AlO, and magnesium spinelle had been formed. This monoxide could not be obtained in a pure condition, but its existence was proved beyond doubt. It is best prepared by heating in a current of hydrogen, a mixture corresponding to

$$Al_2O_3 + Mg = 2AlO + MgO.$$

This oxide is a brownish-black, voluminous powder, is pyrophoric, and liberates H slowly from water; it precipitates cuprous oxide from copper sulphate solution, and is exceedingly susceptible to oxidation.

Winkler suggests that the blue color of sapphire, and possibly also that of ultramarine, may be due to a small proportion of this monoxide.

Of the rare earths of group III., only yttria and lanthania were subjected to the action of magnesium. The energy of the reduction appeared to increase with the atomic weights.

Upon the oxides of the sub-group, Mg reacts with great violence; the intensity of reduction has its maximum in In_2O_3.

The behavior of Th_2O_3 towards magnesium, appears to be an exception. Before the temperature of reduction is reached, this oxide splits up into Th_2O and O_2, and the thallous oxide so formed is then only partially reduced. The

carbonate of thallium, however, is deprived of its O completely and with explosive violence.

GROUP IV.

The most interesting results, perhaps, were obtained in the fourth natural group of elements.

The known properties of C, Si, Ti, Zr, Ce, Th, assign them positions in the main group, while Ge, La, Pb, constitute the sub-group.

In addition to their acid-forming dioxides, the majority of these elements are capable of giving monoxides. It was therefore deemed desirable to attempt not only the complete reduction of the higher oxides, but also a *partial* removal of the oxygen with a view to procure the lower oxides.

The statements of different experimenters concerning the action of CO_2 upon Mg are somewhat conflicting.

That a ribbon of the metal will burn in an atmosphere of CO_2 was first observed by Kessler, but neither he nor other chemists who repeated and modified his experiment explained satisfactorily the nature of the reaction.

Winkler shows, in the first place, that magnesium, when *moderately* heated in a current of CO_2, does not take fire, but is slowly converted at its surface into a carbide, CO being formed at the same time. Upon increasing the heat to a full redness, the metal was inflamed and continued to burn with a dazzling light. The products of this combustion are MgO and C.

When the magnesium is employed in the form of powder, these reactions take place even more readily. At a temperature considerably below a red heat, CO appears and its quantity is greatly increased when low redness is reached. The metal burns with great brilliancy at a full red heat, and unless the current of CO_2 is very rapid, its reduction is complete.

It has already been mentioned that a separation of C was observed when Mg acted upon carbonates; also that CO was formed when an excess of the carbonate was present. Further experiments were made with calcium carbonate. A mixture of this substance with magnesium: $Ca\,CO_3 + 3\,Mg$

$= Ca + C + 3\,MgO$, heated in a current of H, detonated violently. A carbide of magnesium was observed among the debris. No Ca was observed in the residue when only 2 at. of magnesium were used for each molecule of the carbonate.

According to Kessler, burning magnesium is extinguished in CO, while Parkinson asserts that at a red heat the metal burns vividly in this gas. Both observations were found to be correct. A spiral of magnesinm wire ignited in the air, ceased to burn while introduced into a jar of CO, but when strongly heated in a current of the gas the magnesium emitted light, and a gray coating of a carbide appeared on its surface.

Numerous experiments to determine the exact composition of this carbide were made, but without yielding a definite result.

Silicon exhibits a pronounced tendency to combine with Magnesium. Silicon-magnesium was first observed by Wöhler, in 1858.

The reduction of SiO_2 by metallic magnesium was observed 1864, by Phipson, and Parkinson has shown in 1867 that silicon-magnesium, as well as a silicate of magnesium, are formed at the same time. A few years ago L. Gattermann published an interesting paper, in which he showed how very easily silicon dioxide is reduced by magnesium. He states that either silicon or silicon-magnesium can be obtained by varying the proportion of magnesium; and he applies the reaction to the preparation of volatile compounds of silicon, such as the chloride, bromide, iodide, silicoformic acid, silico-chloroform, etc.

Gattermann and Winkler agree that an energetic reaction occurs upon heating a mixture of one molecule of SiO_2 and 2 atoms of magnesium.

$$SiO_2 + 2\,Mg = Si + 2\,MgO.$$

By adding MgO to the mixture, the heat of the reaction was moderated, but it was then found that much silicon-magnesium was contained in the product. If the re-

action be effected at low temperature and in the presence of an excess of magnesium, silicon-magnesium was always formed, while at a high heat or in presence of magnesium, only amorphous silicon resulted.

A monoxide of silicon could not be obtained by the reduction of silica, either by magnesium or silicon.

Many silicates are reduced quite as easily as the dioxide; in some cases the metallic base is likewise reduced, *e. g.*, potash glass.

None of the oxides studied presented greater difficulties than titanium dioxide. The results may thus be summed up: TiO_2 was not reduced to the metallic state; a mixture of monoxide and a titanium spinelle were the products of the reaction. Other intermediate oxides were sometimes formed. When the residue was treated with HCl, HTi_3O_4 was formed, which, upon treating, gave TiO_3 and H. Neither titanium-magnesium, nor a hydride of titanium, was observed.

The reduction of zirconia was effected by heating it with magnesium to a high temperature. A monoxide could not be identified with certainty; and $ZrMg_2$ does not appear capable of existing.

According to the amount of Mg employed either Ce or Ce_2O_3 were obtained from cerium dioxide. An intermediate monoxide was not obtained. The reduction begins at a moderate red heat and is accompanied by a vivid glow. A considerable proportion of the Mg is volatilized. In the nascent state cerium was found to absorb hydrogen in large quantities.

The formation of a metallic hydride at a bright red heat is a most remarkable observation. It is clearly proved to be correct by the following experiment.

A mixture is prepared according to the equation:

$$CeO_2 + 2Mg = Ce + 2\,MgO.$$

Twenty grams of this mixture are placed in a combustion tube through which a current of dry hydrogen is passed, while a gentle heat is applied to expel any moisture. The further end of the tube is then closed with a strong clip.

Hydrogen is allowed to enter the other end and the heat quickly raised to bright redness; a rapid current of hydrogen is seen to pass through the wash bottles into the tube.

The hydride is of a brownish-red color. It is without action on water at ordinary temperatures, but sets free hydrogen upon heating. Hydrochloric acid dissolves it to CeCl, with evolution of hydrogen. It was found impossible to completely remove MgO from the product. The hydride is very imflammable, and detonates with $KClO_3$, KNO_3, etc.

The analytical results obtained point to the formula CeH_2.

After the existence of a hydride of cerium had thus been established, the thought suggested itself that the other elements of group IV. might possibly be capable of forming similar compounds. Only carbon and silicon were known to form hydrides, but these elements could not be made to unite with hydrogen when their oxides were reduced by magnesium. Since titanium could not be reduced to the metal, it is not strange that all efforts to form a hydride gave negative results, zirconium and thorium did absorb hydrogen and yielded hydrides similar to CeH_2. The same was observed with lanthanum and this led Winkler to believe that this element belongs to the cerium group; but he showed subsequently that yttrium and other trivalent elements, and even the divalent barium, strontium and calcium can unite with hydrogen.

These hydrides represent a new class of metallic compounds, in which only half the usual valence of the metals is satisfied.

The action of magnesium upon chlorides has been made the subject of an elaborate research by Seubert and Schmidt.

I must content myself with a very brief statement of some of the main results obtained by these chemists.

Both the anhydrous bodies and the aqueous solutions of the chlorides were subjected to the action of magnesium.

In the former case, the substance, either mixed with magnesium powder, or conducted over it in the form of vapor, was heated to a high temperature. It was found

that all chlorides could thus be reduced to the metallic state, but the reduction was incomplete in the groups of the metals of the alkalis and the metals of the alkaline earths.

In *neutral* aqueous solutions, all the metallic chlorides, save those of the alkalies and those of the alkaline earths, gave up their chlorine to the magnesium. In some cases the metals were deposited in the metallic state, (Ag, Au, Tl, Pb, As, Sb); but in most cases, hydroxides were precipitated. These hydroxides always represent the lowest state of oxidation. $CuCl_2$, *e. g.*, is changed into Cu_2O; Ce, Au, Fe, Mn, all yielded hydroxides.

It would seem that the tendency to form such hydroxides is peculiar to the positive metals, and especially to those forming basic salts. Seubert and Schmidt believed this to be due to a dissociation of the chlorides into hydroxides and hydrochloric acid. They suppose, for instance, that an aqueous solution of $AlCl_3$, contains $Al(OH)_3$, $3HCl$. This view is rendered quite probable by the fact that solutions of Cu, Ni, Co, and Cr exhibit the color of their *hydrated* salts.

Of other metals whose oxides possess a high heat of formation, aluminum has found some application in the reduction of oxides. Beketow has employed it with success to prepare some of the metals of the alkalies; and the experiments of Greene and Wahl of reducing manganese oxides by means of the metallic aluminum are still fresh in our memory.

I am convinced that a continued study of the relative affinities of the metals for oxygen and other negative elements, will lead to important applications in metallurgy, and give new and valuable methods to synthetic and analytical chemistry.

BOOK NOTICES.

A Treatise on Elementary Hydrostatics. By John Greaves, M.A. Cambridge University Press. 1894. Price, $1.10.

A school-book, modeled after the excellent works of Rev. J. B. Lock, upon mechanics and mathematics, published by the Messrs. Macmillan. As is proper in such a work, each chapter is followed by a number of practical examples for solution. The book embraces chapters upon capillarity and upon the statics of gases. T.

The Chronicle Fire Tables for 1894. A record of the fire losses in the United States by States and Territories during 1893, etc. New York: The Chronicle Company, Ltd. Price, $5.

This large octavo volume of reliable annual fire data comes in suggestive crimson binding, with over 400 pages. The general arrangement is similar to that of former years. It shows, *inter alia*, the progression of the total annual fire losses. In 1890, they amounted to $109,000,000; 1891, $144,000,000; 1892, $152,000,000; and in 1893, the largest of all, $168,000,000. To see these immense losses properly arranged and classified for study and reference, and to know that it is all accurately done, is not only encouraging to the efforts of those using such data, but is a source of real satisfaction. The diagrams and tables herein, showing the quantity and movement of fire losses in the United States for twenty years, are very interesting and become annually more so.

A remarkable fact is shown in one of the tables—that though the actual increase in fire losses, 1890 to 1893 inclusive, has been so great, as above shown, there has been a steady diminution of the *average* property fire loss from $7,285 in 1885, to $4,761 in 1893; and in the *average* insurance loss, from $4,069 in 1885, to $3,012 in 1893. This shows, mainly, that improved fire-extinguishing apparatus, improved modes of building, and increased care of fire underwriters, are showing their good effects. Without such efforts and improvements, had these matters gone on as ten or fifteen years ago, the fire losses would probably have reached $250,000,000 in the United States for 1893.

The principal excellent tabulations show the fire losses in each State and Territory by classes of risks. There is a general table showing the number of fires by classes, property loss and insurance loss, with all the known causes by numbers (together with the unknown) appended to each class. This, though not as long as others, is one of the very best of the tabulations. Another general, and similarly arranged table, gives the fires and losses by causes (the last-named put first) and appended is the character of each risk where the fire originated. Another similar table gives the fire and losses by specified industries.

There are many other tabulations, and some graphic diagrams which we would like to mention, but want of space prevents. In brief, this standard

annual is fully up to the merit of its other recent issues, and in some respects shows improvement thereon. We unhesitatingly recommend it as containing the best arranged and the fullest fire data obtainable anywhere, and we pronounce the "Chronicle Fire Tables" to be superior to any other such data yet attempted in the world. N.

Franklin Institute.

[*Proceedings of the stated meeting, held Wednesday, September 19, 1894*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, Sept. 19, 1894

PROF. E. J. HOUSTON in the chair.

Present, seventy-two members and twenty-four visitors.

Additions to membership reported since the stated meeting of June, 1894, twenty-two.

The Secretary presented a communication from a committee appointed by the Royal Society of London, to inquire into, and report upon, the feasibility of preparing, by international co-operation, a complete catalogue of scientific publications, and requesting the views of the Franklin Institute respecting the project. On motion, it was voted to refer the matter to the Committee on Library, with the request to give it proper consideration, and with authority to transmit its conclusions to the Committee of the Royal Society.

After lengthy discussion *pro* and *con*, the following amendments to the by-laws of the Institute were adopted, viz.:

On the recommendation of the Board of Managers

ARTICLE II, Section 1 (paragraph 4).—Amended by striking out the words "*three* dollars" and substituting in place thereof the words *six* dollars.*

ARTICLE III, Section 6.—Amended by striking out the words "*fifty* cents" and inserting in place thereof the words *seventy-five* cents.

ARTICLE IV, Section 1.—Amended by striking out the words "five dollars," and inserting in place of them the words "eight dollars;" and further by striking out the words "fifty dollars," and inserting in place of them the words "one hundred dollars."

ARTICLE IV, Section 4.—Amended by striking out the words "fifty cents," and inserting in place of them the words "seventy-five cents."

Offered by Mr. Henry R. Heyl:

ARTICLE III. *Members.*—Amended to read as follows:

SECTION 1.—The members of the Institute shall consist of manufacturers, mechanics, artisans, and persons friendly to the mechanic arts, and they may be either annual contributors, life members, permanent members, holders of second-class stock, honorary or corresponding members.

*Adopted by vote of the stockholders present.

SECTION 3.—The privileges of membership in the Institute shall extend only to persons of legal age who are not in arrears and who shall have signed the charter and by-laws.

ARTICLE IV. *Payments.*—Amended to read as follows:

SECTION 1.—The annual dues of contributing members shall be eight dollars; a life membership (not transferable) may be acquired by the payment of one hundred dollars within any one year, and a permanent membership may be granted to any one who shall, within any one year, contribute to the Institute the sum of one thousand dollars, which membership may be transferred by will or otherwise.

SEC. 5.—The annual dues from contributing members may be applied to the current expenses of the Institute, but all moneys received from life and permanent membership shall be vested in the Board of Trustees, the income therefrom only to be applied to the maintenance fund.

Mr. Alfred Goldstein presented a paper on "A Standard System of Automatic Fire-alarm Protection," illustrated by a working specimen of the apparatus employed, exhibiting the operation of the system. The system is that of The Pneumatic Fire Alarm Telegraph Company, and has received the endorsement of the Board of Fire Underwriters in various cities. The Hall of the Institute is protected by this system. (Referred for publication.)

Mr. W. N. Jennings exhibited some striking photographic views of the new Tower Bridge over the Thames, at London. Description of an exhibit of some remarkable aluminum castings, made by William S. Cooper, of Philadelphia, was deferred on account of the lateness of the hour.

Adjourned. WM. H. WAHL. *Secretary.*

ERRATUM.

Article.—Kebler, Interaction of Borax, etc. On p. 238, September, 1894, several errors occur in the equations. The correct reading is given below:

(1) $2C_3H_5(OH)_3 + Na_2B_4O_7 = 2C_3H_5BO_3 + 2NaBO_2 + 3H_2O$.

(2) $2C_3H_5(OH)_3 + Na_2B_4O_7 + 3H_2O = 2C_3H_8(OH)_3 + 2H_3BO_3 + 2NaBO_2$.

(3) $C_3H_8BO_3 + 3H_2O = C_3H_5(OH)_3 + H_3BO_3$.

(4) $3Na_2CO_3 + 2H_3BO_3 = 2Na_3BO_3 + 3CO_2 + 3H_2O$.

PENNSYLVANIA STATE WEATHER SERVICE,

UNDER THE DIRECTION OF THE FRANKLIN INSTITUTE,

CO-OPERATING WITH THE

UNITED STATES DEPARTMENT OF AGRICULTURE, WEATHER BUREAU.

T. F. TOWNSEND, WEATHER BUREAU, OBSERVER IN CHARGE.

MONTHLY WEATHER REVIEW.

FOR SEPTEMBER, 1894.

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, September 30, 1894.

GENERAL REVIEW.

The average temperature for September, 1894, 66°·6, is 4°·5 above the average (62°·1) for the past six years.

The highest recorded temperatures occurred on the 2d, 3d, 10th, 11th and 15th, and were as follows: Saegerstown, 95°; Huntingdon, 94°, and 92° at ten stations.

The lowest were on the 25th and 26th. Shingle House, 24°; Lock Haven, 26°; Smethport, 28°, and Wellsboro, 28°.

The drought which began in July was broken September 8th, when general rains occurred. The effect of the drought on crops was very damaging in nearly all parts of the State.

From January 1, 1894, to September 30, 1894, the accumulated excess in daily mean temperature at Philadelphia was 498°; at Erie, 673°, and at Pittsburg, 635°.

For the same period the deficiency in precipitation at Philadelphia was 3·29; Erie, 5·19, and Pittsburgh, 7·92.

TEMPERATURE.

	Mean Temperature.	*Mean Precipitation, Inches.*
September, 1888, ...	59°·0	4·84
1889, ...	61°·9	5·05
1890, ...	62°·0	4·57
1891, ...	66°·4	2·39
1892, ...	62°·3	2·81
1893, ...	60°·9	2·67
1894, ...	66°·6	6·30

The means of the daily maximum and minimum temperatures, 76°·8 and 56°·4, respectively, give a monthly mean of 66°·6, which is 5°·7 above the corresponding month of 1893.

The average daily range was 20°·4.

Highest monthly mean, 70°·0 at Pittsburg and *Philadelphia* [Weather Bureau].

Lowest monthly mean, 60°·6 at Wellsboro.

Highest temperature recorded during the month, 95° on the 2d at Saegerstown.

Lowest temperature, 24° on the 26th at Shingle House.

Greatest local monthly range, 68° at Shingle House.

Least local monthly range, 44° at Cassandria, Lancaster and Swarthmore.

Greatest daily range, 55° at Lock Haven.

PRECIPITATION.

The average precipitation for the State, for the month, 6·30 inches, is 2·58 inches more than the average [3·72] for the last six years.

Excessive rains occurred at 24 stations. On the 8th, 3·20 inches fell in 40 minutes at Bethlehem. On the 18th, at Smith's Corner, 7·70 inches fell in 12 hours, and 7·32 inches at Point Pleasant in 7 hours and 40 minutes.

The largest monthly totals were: Clarion, 12·36; Smith's Corner, 11·61; Point Pleasant, 10·67; Parker's Landing, 9·82; Carlisle, 9·45, and Brower's Lock, 9·27.

The least were: Chambersburg, 2·82; Somerset, 3·12; Davis Island Dam, 3·13; West Newton, 3·20; Confluence, 3·48, and Pittsburg, 3·68.

WIND AND WEATHER.

The prevailing wind was from the West.

Average number: rainy days, 10; clear days, 10; fair days, 10; cloudy days, 10.

BAROMETER.

The mean pressure for the month, 30·09, is about ·01 above the normal. At the United States Weather Bureau Stations, the highest observed was 30·55 at Philadelphia on the 13th, and the lowest 29·70 at Philadelphia on the 19th.

MISCELLANEOUS PHENOMENA.

Thunder Storms.—Pittsburg, 7th, 9th, 13th; Hollidaysburg, 7th, 8th, 9th, 14th, 15th, 16th; Le Roy, 5th, 8th, 10th; Quakertown, 8th, 10th, 16th, 18th; Cassandria, 7th, 8th, 9th, 10th, 16th; Johnstown, 7th, 8th, 9th, 14th, 16th, 30th; Emporium, 7th, 8th, 10th, 15th, 16th; E. Mauch Chunk, 8th; State College, 9th; West Chester, 8th, 10th, 18th; Coatesville, 9th, 10th, 16th, 18th; Kennett Square, 8th, 9th; Westtown, 8th, 10th, 19th; Grampian, 8th; Lock Haven, 5th, 8th, 14th, 16th; Saegerstown, 6th, 7th, 10th, 12th, 15th; Carlisle, 8th, 17th, 18th; Harrisburg, 8th, 9th, 10th, 16th, 18th; Swarthmore, 8th, 9th, 16th; Uniontown, 6th, 7th, 9th, 10th, 14th, 16th, 19th; Huntingdon, 8th, 9th, 14th, 16th; Lancaster, 8th, 10th, 16th; Coopersburg, 8th, 10th, 16th, 18th;

Wilkes-Barre, 8th, 13th, 16th, 19th; Pottstown, 8th, 10th, 16th; Easton, 8th, 9th, 10th, 16th, 18th; Logania, 8th, 9th, 16th, 18th; *Philadelphia* [Weather Bureau], 8th, 9th, 10th, 18th; [Centennial Avenue], 8th, 9th, 10th; Blooming Grove, 8th, 10th, 14th, 16th; Somerset, 7th; Wellsboro, 5th, 8th, 10th, 15th, 16th; Lewisburg, 8th, 18th; Dyberry, 8th, 16th; Hamlinton, 8th, 10th, 16th; South Eaton, 8th, 10th, 16th; York, 8th, 9th, 10th, 16th, 18th; Lebanon, 8th, 9th, 10th, 16th.

Hail.—Cassandria, 10th; Pottstown, 8th; Phœnixville, 8th.

Frost.—Hollidaysburg, 26th; Le Roy, 26th; Quakertown, 26th; Cassandria, 12th, 25th, 26th; Johnstown, 24th, 25th; Emporium, 26th; East Mauch Chunk, 26th; State College, 26th; Coatesville, 25th, 26th; Grampian, 12th, 26th; Lock Haven, 12th, 24th, 25th, 26th; Saegerstown, 26th; Carlisle, 26th; Harrisburg, 26th; Edinboro, 26th; Uniontown, 25th; Huntingdon, 25th, 26th; Coopersburg, 12th, 26th; Drifton, 26th; Wilkes-Barre, 27th; Kane, 26th; Smethport, 25th; Logania, 26th; Blooming Grove, 25th, 26th; Shingle House, 12th, 26th; Selins Grove, 26th; Somerset, 25th, 26th, 30th; Wellsboro, 12th, 26th; Lewisburg, 26th; Dyberry, 12th, 13th, 25th, 26th; Honesdale, 26th; Hamilton, 26th; South Eaton, 26th; York, 26th; Phœnixville, 26th; Lebanon, 12th, 26th; Greenville, 26th.

Aurora.—Le Roy, 21st; Kane, 14th.

Solar Halo.—Philadelphia [Weather Bureau], 26th; [Centennial Avenue], 26th; Wellsboro, 18th.

Lunar Halo.—Philadelphia [Centennial Avenue], 11th; Wellsboro, 17th.

Monthly Summary of Reports by Voluntary Observers of the Pennsylvania State Weather Service for September, 1894.

County.	Station	Elevation above Sea Level (feet).	Temperature.								Precipitation.			Number of Days.			Wind. Prevailing Direction.	Observers
			Mean.	Maximum.		Minimum.		Mean of Maximum.	Mean of Minimum.	Daily Range.		Total Inches.	Total Snowfall During Month.	Depth of Snow on Ground at End of Month.	Number of Days Rain or Snow.	Clear.	Fair.	Cloudy.		
				Highest.	Date.	Lowest.	Date.			Mean.	Greatest.									
Allegheny,	Pittsburgh,	820	70°0	92	3	43	26	79°3	61°4	17°9	35	3°68			11	9	11	10	SE	O. D. Stewart, W. B
Berks,	Hamburg,	380	68°2	90	10	42	26	77°8	58°6	19°2	32	6°25			7	9	14	7	E	William Shipe.
Berks,	Reading,[2]	280	65°6	. .	. .	. .	. .	. .	. .	. .	. .	7°48			16	. .	. .	. .	. .	Franklin Yager.
Blair,	Altoona,	1,181	68°3	87	3, 4	40	26	76°8	61°0	15°8	28	5°25			11	. .	. .	. .	. .	Dr. C. B. Dudley.
Blair,	Hollidaysburg,	947	66°7	92	2	32	26	78°8	54°6	24°2	38	3°66			13	12	8	10	W	Prof. J. A. Stewart.
Bradford,	Le Roy,	1,400	64°1	90	2	32	26	73°9	55°1	18°1	32	5°44			10	11	10	9	SW	O. W. T. Warburton
Bucks,	Forks of Neshammy[1] (22 days),	300	65°4	. .	. .	. .	. .	. .	. .	. .	. .	6°34			9	8	4	10	N	J. C. Hilleman.
Bucks,	Quakertown,	536	66°2	90	10	34	26	77°5	55°2	22°4	39	7°22			7	8	18	4	SW	J. L. Hancock.
Cambria,	Cassandria,	2,120	66°8	84	2,[3]	40	26	72°9	60°6	12°3	31	5°85			12	6	18	6	NW	A. H. Boyle.
Cambria,	Johnstown,	1,184	68°7	94	2	37	26	80°2	57°2	23°0	42	5°44			15	8	13	9	. .	R. C. Lacosta.
Cameron,	Emporium,	1,050	64°4	88	2	31	26	75°4	54°1	21°3	39	5°06			12	13	7	10	E	T. B. Lloyd.
Carbon,	E. Mauch Chunk,	550	65°8	91	2	32	26	76°2	55°4	20°8	42	5°63			9	13	8	9	S	F. C. Wintermute.
Centre,	State College (29 days)— Agricultural Experiment Sta.,	1,192	66°0	89	2	34	26	73°2	56°9	16°3	36	5°78			10	6	9	14	S	Prof. Wm. Frear.
Chester,	West Chester,	455	68°2	90	10	42	26	75°7	60°6	15°1	24	6°84			8	11	4	15	S	J. C. Green, D.D.S.
Chester,	Contesville,	380	68°0	91	10	37	26	77°8	58°2	19°7	34	8°42			6	11	12	7	S	W. T. Gordon.
Chester,	Kennett Square,	275	68°4	91	10	40	26	77°8	58°9	18°9	29	7°71			9	12	3	15	NE	B. F. Kirk.
Chester,	Phœnixville,	190	68°3	91	10	37	26	77°2	59°4	17°8	33	7°41			9	9	7	15	NW	Knowles Crowley.
Chester,	Westtown (24 days),	350	66°4	89	10	40	26	74°2	58°5	15°7	28	5°83			7	9	3	18	W	John D. Carter.
Clearfield,	Georgian,	1,450	64°9	88	2	36	26	73°4	56°4	17°0	32	7°08			11	5	13	12	SW	Nathan Moore.
Clinton,	Lock Haven,	560	62°2	92	2	26	25	82°2	42°0	40°2	55	6°46			12	14	5	11	W	Prof. J. A. Robb.
Columbia,	Bloomsburg— State Normal School,	500	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .			. .	. .	. .	. .	. .	Prof. J. G. Cope.
Crawford,	Saegerstown,	1,200	63°8	95	2	30	26	78°8	48°7	30°1	53	6°24			12	12	6	9	N	J. G. Apple.
Cumberland,	Carlisle,	480	68°6	90	2	36	26	78°2	59°1	19°1	36	9°45			10	13	6	11	S	J. E. Fogus.
Dauphin,	Harrisburg,	480	68°0	88	10	40	26	76°1	60°6	15°5	28	5°53			9	11	8	11	E	F. Ridgway, W. B.
Delaware,	Swarthmore— Swarthmore College,	361	69°4	89	10	45	26	76°6	62°3	14°3	26	5°50			6	8	7	15	NE	Prof. S. J. Cunningham.
Erie,	Edinboro,[2]	190	64°6	90	3	33	26	. .	. .	. .	. .	. .			. .	17	8	5	S	C. F. Sweet.
Erie,	Erie,	1,400	67°0	90	15	36	27	76°0	59°0	17°0	35	5°48			13	10	13	7	S	P. Wood, W. B.
Fayette,	Uniontown,	881	66°8	91	2	40	25	78°6	58°3	19°7	32	5°77			12	11	14	5	SW	Wm. Hunt.
Franklin,	Chambersburg (29 days),	1,000	66°1	90	9	40	26	78°6	57°6	21°0	34	8°62			6	5	9	15	W	J. C. Boggs.
Huntingdon,	Huntingdon— The Normal College,	650	66°9	94	2	33	26	78°6	55°2	23°4	45	7°56			11	12	8	10	W	Prof. W. J. Swigart.
Lancaster,	Lancaster— Franklin and Marshall Col'ge,	413	69°0	90	11	46	25	79°7	58°2	21°5	35	7°32			7	11	14	5	W	W. E. Bushong.
Lebanon,	Lebanon,	458	67°3	89	10	36	26	77°6	57°0	20°6	35	5°47			9	9	8	13	SW	G. W. Hayes, C. E.
Lehigh,	Coopersburg,	320	66°8	87	2	39	26	74°0	59°7	14°3	28	5°86			10	10	13	7	SE	Dr. M. H. Boyer.
Luzerne,	Drifton (25 days),	2,583	63°6	85	6, 7	40	29	75°2	52°0	19°2	31	4°65			10	9	6	10	E	J. R. Wagner.
Luzerne,	Wilkes-Barre,	575	66°0	89	10, 15	32	26	77°7	54°2	23°5	38	5°05			9	13	10	7	W	A. W. Betterly.
McKean,	Kane,	2,000	63°2	89	2, 3	33	26	73°7	52°8	20°9	36	6°97			12	9	13	8	SW	C. H. Kemp.
McKean,	Smethport,	1,500	62°8	92	2	28	26	75°6	49°9	25°7	49	6°32			8	17	5	8	SE	Armstrong & Brownell.
Mercer,	Greenville— Thiel College (24 days)	1,000	62°8	92	8	35	26	76°0	49°6	26°4	48	6°03			12	8	5	11	. .	Prof. S. H. Miller.
Montgomery,	Pottstown,	150	67°9	87	2, 9	40	26	77°0	58°8	18°2	32	7°94			8	10	9	11	W	Charles Moore, D.D.S.
Northampton,	Easton— Lafayette College,	325	66°0	88	2	37	26	75°9	56°1	19°8	36	6°57			7	10	7	13	. .	J. W. Moore.
Perry,	(Aqueduct) Logania,	367	69°5	92	9, 10	37	26	79°2	59°8	19°4	36	5°68			11	10	6	14	SE	Richard Callin.
Philadelphia,	U. S. Weather Bureau,	117	70°0	91	10	44	26	77°4	62°7	14°5	21	5°11			8	10	8	12	SW	John Comly.
Philadelphia,	1529 Centennial Avenue,	120	69°8	91	10	43	26	77°4	62°3	15°1	24	5°57			8	10	8	12	W	John Grathwohl.
Pike,	Bloomings Grove,[2]	. .	63°5	89	2	30	26	. .	. .	. .	. .	4°80			6	6	17	7	W	C. D. Voorhees, M.D.
Potter,	Shingle House,	1,475	62°4	92	2	24	26	76°1	48°6	27°5	49	5°96			11	10	8	12	W	J. M. Boyer.
Snyder,	Selins Grove,	455	64°8	90	3, 5	33	26	78°7	51°0	27°7	46	4°25			10	. .	23	7	SW	W. M. Schrock.
Somerset,	Somerset,	2,250	65°8	90	5, 15	34	26	79°0	52°5	26°5	42	3°12			8	4	17	9	NW	H. D. Deming
Tioga,	Wellsboro,[2]	1,327	60°6	88	2, 15	28	26	. .	. .	. .	. .	3°85			8	11	8	11	S	Prof. W. G. Owen
Union,	Lewisburg (28 days),	450	67°2	92	2	34	26	78°7	55°5	23°4	44	5°09			9	6	7	15	S	Theodore Day.
Wayne,	Dyberry,	1,100	62°3	88	10	26	26	75°2	49°4	25°8	42	4°40			10	13	10	7	NW	Andrew Thompson
Wayne,	Honesdale,	1,000	63°7	83	10	30	26	73°1	54°3	18°8	32	4°47			15	12	9	9	W	T. B. Orchard, M.D.
Wayne,	(Salem Corners) Hamlinton,	1,600	64°6	87	5	31	26	73°3	56°0	17°3	30	5°67			12	6	12	12	W	Murray Forbes.
Westmoreland,	(Immel Reservoir) Lycippus,	1,480	68°1	92	4	42	25	77°9	59°0	18°9	33	7°68			8	. .	. .	. .	. .	C. D. Ambrose.
Westmoreland,	Ligonier,	1,730	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .			. .	. .	. .	. .	. .	B. M. Hall.
Wyoming,	South Eaton,	860	64°6	87	2, 10	33	26	74°6	54°6	20°0	38	3°69			9	17	6	7	NW	Mrs. L. H. Grenewald.
York,	York,	385	68°2	91	10	39	26	78°0	54°8	19°6	34	9°16			10	10	10	10	. .	

Mean temperature from maximum and minimum readings. [2] Extremes from dry thermometers. [1] Mean temperatures, 7 + 2 + 9 + 9 + 4. [3] Mean temperature 8 + 8 + 2,

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	Total.
Delaware Basin.																																
Bethlehem,						.22		4.67		.91				.24		.11		1.16	1.33													8.54
Blooming Grove,							.60	.15		.27				.55		.29			2.04													4.60
Brewers Lock,								.30	3.93		.39							3.17	1.48													9.27
Coatesville,								2.93	.76	.65						.09		.78	3.27													8.42
Coopersburg,						.77		1.21	.04	.66				.06		.31	.10	1.48	1.22									.01				5.86
Doylestown,						.09	4.00		.05	.44						.02		2.45	1.65	.15												8.78
Dyberry,						.72		.23		.35				.30	.17	.38		.13	1.87	.13			.19									4.40
Easton,						.08			1.13	.98																				.01		6.57
Forks of Neshaminy,						.03		3.33	.22	.41				.04		.08	.32	1.26	3.90													6.94
Frederick,						.03	.06	2.51	.21	.49				.12		.05	.08	2.83	2.39											.08		7.19
Hamburg,						.44		1.24		.40				.13		.28		1.44	2.32													6.25
Honesdale,						.62		.47	.01	.47	.09		.01	.10	.05	.20	.17	.17	1.81	.16			.14	.01									4.47
Kennett Square,							.25	.04	2.80	.57							.11	1.32	2.60							.01	.01					7.71
Lansdale,							.83	3.60		.60					.21	.16		1.98		.37												8.84
Mauch Chunk,						.03		1.11	.03	.25				.43		.07		.75	2.87	.09												5.63
Ottsville,						.09		1.00	.09	.72				.02		.36	.23	4.21	1.48	.04										.03		8.27
Philadelphia, a†							.01	.82	1.14	.75								.55	1.13	.70												5.11
Philadelphia, b,						.01		.01	.80	1.68	.83							1.10	1.55	.30												6.57
Phoenixville,								2.38		.73				.05			3.10	1.50	.03											.02		8.31
Point Pleasant,						.12		.95		.53						.21	.05	7.32	1.49													10.67
Pottstown,						.07		4.17		.55				.07		.13		.80	2.15													7.94
Quakertown,						.40		1.64		.59						.51		2.78	1.23	.05												7.22
Reading,					.01	.01	.05	2.55	.20	1.01				.13	.02	.20	.20		.65	2.38	.01						.01	.01		.01		7.48
(Seisen Corners) Hamlinton,						.46		.41	.10	.02	.56			.50		.13	.60	.10	1.38	4.33				.08								5.67
Selinsgrove,						.48		1.06	.09	.63				.10		.14	.07	1.06	1.96	.01												5.60
Smith's Corner,						.17		.98	.03	.51				.05		.28	.21	7.70	1.55	.05										.08		11.61
Swarthmore,							.10	1.85	.44	.51	*								‖2.60													5.30
West Chester,							.09	1.54	.70	.51								.06	1.36	1.97							.01					6.84
Westtown,	*	*	*	*			.07	1.95	*	.40						.04	1.45	1.92														5.83
Susquehanna Basin.																																
Altoona,						.15		.42	1.12	.66	.38			.10	.22	.45	.07		1.10	.58												5.25
(Aqueduct) Logania,							.46	.34	1.74	.22				.02		.50	.02	1.39	.96	.01							.02					5.68
Bloomsburg,																																
Carlisle,						.08	.90	2.00	1.20	1.28						.25	.10	2.40	2.10								.20					9.45
Drifton,		*				.43	.31	.06	*	.37																						
Emporium,							.05	.86	.15	.88				.03	.35			1.26	.49	.50			*							*		4.65
Gettysburg,							.05	1.82	.17	.60				.11	.17	.10	.43	.30	1.76	.40										.05		5.96
Girardville,																	1.40	.52	2.50	.23												7.60
Grampian,								1.59		.39					.27	.28		2.04	1.11	.06									.11			5.74
Harrisburg,†						.72	1.98	.11	.09					.13	.41		.34	.70	1.80	.18												7.08
Hollidaysburg,						.46	.72	.62	.58								.57	.02	1.32	1.96												5.53
Huntingdon,						.05	.51	.73	.20					.05	.09	.13	1.29		1.23	1.25	.08											5.68
Kilmer,						.13	.05	.58	2.83	.20																						
Lancaster,							.20	1.60	.27	.11				.55		.85	.10	.75	1.50	.02												7.56
Lebanon,								‡2.74		.84									‖3.87	.02												5.47
Le Roy,							.71	.64	.44	.16									‖6.66													5.47
Lewisburg,						.70		.59	.02	.86				.05		.61	.01	.73	2.12													7.39
Lock Haven,														.06	.08				1.08													5.47
Selins Grove,						.35	.15	1.93	.08	.46						.01			1.00	.12			.16									5.44
South Eaton,					.44		.05	1.45	.94	.70				.29		.69		.77	1.17			*	*									5.09
State College,															.60	.02	.10	.11	.22	1.51	.02											6.46
Wellsboro,						.21	.23	.32	.45					.18			.30	.01	.93	1.50	.12											4.25
Wilkes-Barre,						.55		.20		.39	.04			.05		.34			1.85	.12												3.69
York,					.40		.08	1.31	1.28	.27						.01	.01	.04	.45	2.61	.12				*							5.78
								.75		1.90						.40	.35		.20	2.30	.15											5.85
					1.05			.17		.60				.27			.67	.36	1.57		.29		.07									5.05
						2.23		1.00	.80	.19						.20	2.60	.08	.89	1.15							.02					9.16

†U. S. Weather Bureau Stations. *Missing. ‡Total rainfall for 18th and 19th. ‖Total rainfall from 16th to 19th, inclusive. ‡Total rainfall from 6th to 8th, inclusive.

URING SEPTEMBER, 1894.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	Total.
Ohio Basin.																																
Beaver Dam,								.15	.32	.72	.36			.08		.20			.54	1.38												3.74
Brookville,								.52	2.27	.76	.05			.54	.42	.68	.03	.11	.67	1.41	.07												8.72
Cassandria,							.07	1.06	.34	.60	.50	.03				.34	.16	.41	1.42	.30							.02						5.23
Clarion,								1.76	2.32	1.38	2.21		.07	.95	.77	1.14	.02	.12	.34	2.25	.07		.01	.02								12.36
Confluence,								.05	.45		.23	.48			.02	.38	.03		.81	.93	.10											3.48
Davis Island Dam,									.30		.14	.29		.01	.16	.96	.07	.03		.61	1.45	.01										3.13
DuBois,									1.15	1.27	.05	.70			.33	.60	.18	.01	.03	1.17	2.16	.07										7.72
Elwood Junction,									.20		1.11	.50		.04		.06	.10			.40	2.32	.10										4.83
Freeport,								.03	.41	.38	.07	.45		.18	.15	.27	.27	.03	.48	.28	.92	.17			.02							3.01
Greensboro,									.40		.25	.50			.20		.55	.06		1.00	.75	.02										3.73
Greenville,								.12	.18	.02	1.55			.50	.19	.32		.01	.57	.65	1.89		.03									6.03
(Immel Reservoir)																																
Lycippus,							1.80	1.07	.40	.57				1.00		.06			.70	2.08												7.68
Johnstown,						.02	.68	.65	.04	.37			.03	.10	.27	.65	.16	.40	1.41	.64	.01								.09			5.44
Kane,							.27	.64	.06	1.06			.21	.49	.23	1.18	.03	.14	1.00	.46												6.97
Ligonier,																																
Lock No. 4,							.01		.35	.68	.36		.02	.24		.08	.35		.56	1.42	.02								.08			4.19
Mahoning,								.42	.23	.51	1.04			.38		.26	.16	.58	.43	3.60	.08		.09									7.91
Oil City,								.31	1.05	.26	1.15		.09	.56	.08	.48	.03		.31	2.20	.06		.01	.02								6.31
Parker's Landing,								.32	.78	.10	1.07		.18	1.20	.30	.51	.01	.03	.30	4.81	.04			.07								9.82
Pittsburg,†							.49	.05	.30	.43			.05	.01		.17		.04	.26	1.26									.02			3.68
Ridgway,								.06	.83	.41	1.01		.28		.16	.38				1.50												3.73
Saegerstown,					.05		.05	.60		.70			.30	.15	.35	.40			.20	1.40			.26		.08							6.24
Saltsburg,						.20	.02	.70	.02	.10	.60		.02	1.33		.14	.04		.82	2.48	.21											6.58
Shingle House,								1.48	.23	.40			.06	.28	.20	.63		.07	1.34	.39			.08									5.96
Smethport,								.75	.12	.40				.40		1.50			1.65	.45			.05									6.32
Somerset,							.51		.56	.36			.01		.33			.02	.65	.20												3.28
Stoyestown,							.52	2.01	.37	.22	.60			.13	.17	.29	.26	.11	.60	.91	.23												6.39
Uniontown,							.07		.20	.36			.20	.08		1.25	.22	.24	.34	1.32												5.77
Warren,						.20		.91	.82	.05	.59			.19	.61	.32	.01		.24	.93	.03		.33										6.24
West Newton,								.20		.10	.27				.18			.27	.53	1.02	.23											3.20
Potomac Basin.																																
Chambersburg,							.14		.19	.11						.51		.22	.95						•							2.82
Lake Basin.																																
Erie,†						.26	.04	.28	.14	.07			.49	.02	.10	.14			.48	1.68		.02	.26										5.48

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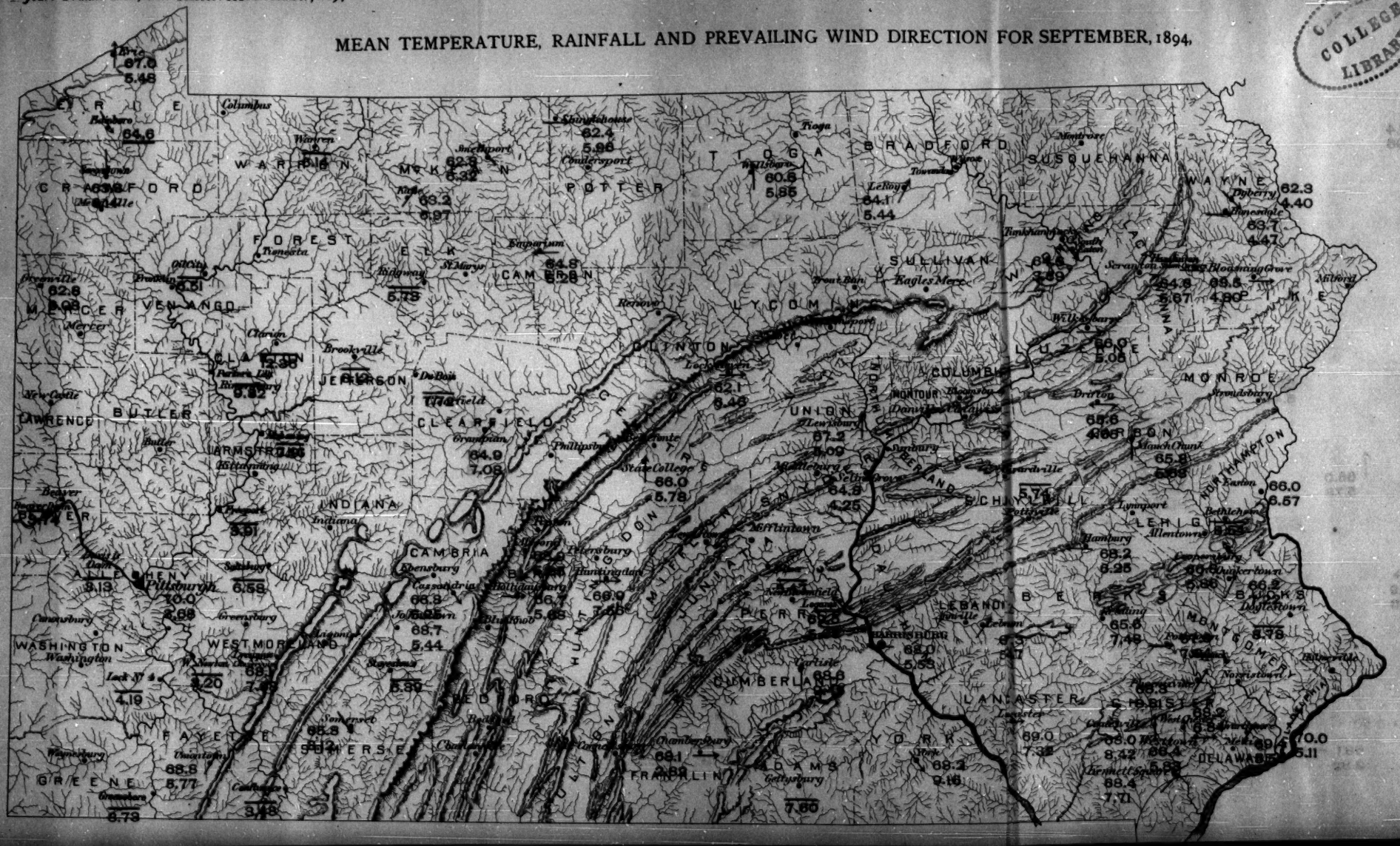
MEAN TEMPERATURE, RAINFALL AND PREVAILING WIND DIRECTION FOR SEPTEMBER, 1894.